SCS STUDY REPORT - VOLUME 4

SPACE STATION
SIMULATION COMPUTER SYSTEM (SCS) STUDY
for
NASA/MSFC

CONCEPTUAL DESIGN REPORT

TRW-SCS-89-T4

31 October, 1989

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Subject: Contract No. NAS8-37745/P00002
Final Technical Report
Simulation Computer System for Space
Station Program

In accordance with the requirements of the subject contract, the final technical report titled SCS Study Report, consisting of six volumes is herewith submitted and distributed as shown.

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SPACE STATION SIMULATION COMPUTER SYSTEM (SCS)
STUDY

CONCEPTUAL DESIGN REPORT

SCS SCS

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CDRL: TRW-SCS-89-T4

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INTRODUCTION

The Simulation Computer System (SCS) is the computer hardware, software, and workstations that will support the Payload Training Complex (PTC) at MSFC. The PTC will train the Space Station payload scientists, station scientists, and ground controllers to operate the wide variety of experiments that will be onboard the Space Station Freedom.

This SCS Conceptual Design Report summarizes the analysis performed on the SCS Study as part of Task 4 - Develop SCS Conceptual Designs - of the SCS Study contract. This work was performed to explore the spectrum of possible top level architectural designs applicable to the SCS.

In the first step of this task, a methodology was developed to ensure that all relevant design dimensions were addressed, and that all feasible designs could be considered. The development effort yielded the following method for generating and comparing designs in Task 4:

1. Extract SCS system requirements (functions) from the system specification.

2. Develop design evaluation criteria.

3. Identify system architectural dimensions relevant to SCS system designs.

4. Develop conceptual designs based on the system requirements and architectural dimensions identified in step 1 and step 3 above.

5. Evaluate the designs with respect to the design evaluation criteria developed in step 2 above.

The results of the method, detailed in the above 5 steps are discussed in corresponding sections 1 through 5 of this report. The results of the Task 4 work provide the set of designs (shown in Sections 4.0 and 6.0) , from which two or three candidate designs are to be selected by MSFC as input to Task 5 - Refine SCS Conceptual Designs. The designs selected for refinement will be developed to a lower level of detail, and further analyses will be done to begin to determine the size and speed of the components required to implement these designs.

MSFC is responsible for approving this SCS Conceptual Design Report. TRW will assume MSFC approval of this report in the absence of any specific MSFC disapproval within 30 days of delivery of this report to MSFC. However, it is TRW's current intention to include this report as a chapter or appendix in the SCS Final Study Report, and thus any comments or additions that are relevant and important are solicited.

1.0 SCS SYSTEM REQUIREMENTS (FUNCTIONS)

The SCS Requirements Functions were developed from the SCS Specification as a method to ensure that the candidate designs meet all of the SCS requirements. These functions were developed by careful review of the written requirements, and by utilization of the knowledge and assumptions resulting from the Study Issues and Study Analysis efforts. These essential SCS functions are:

DMS REPRESENTATION. Includes all the DMS functions needed to support payload training. This function could be performed by DMS Kits or software simulations of DMS functions.

CORE SYSTEM REPRESENTATION. Includes all the Operations Management System (OMS) and Operations Management Application (OMA) functions needed to support payload training. Also includes interfaces to other core systems required by payload, e.g. Electrical Power System (EPS), Thermal Control System (TCS). If DMS Kits are used, this function would be provided by software running on a simulation host or the DMS Kit hardware.

C&T SYSTEM REPRESENTATION. Includes uplink and downlink communication to the POIC and onboard high rate science data streams. The C&T System Representation is a subfunction of the Core System Representation.

PAYLOAD REPRESENTATION. Includes payload simulations constructed using only software, simulators consisting solely of flight equivalent payload hardware and associated software, and hybrid payload simulators which use a mixture of hardware and software to simulate a payload.

CREW INTERFACE REPRESENTATION. Includes Multipurpose Application Consoles (MPACs), Command and Display (C&D) panels for the experiments, and the Element Control Work Station (ECWS). These may be flight equivalent hardware and software, or functional approximations thereof. Caution and Warning (C&W) panels are provided as part of the PTC, and are not part of the SCS.

SIMULATION EXECUTIVES. Includes the executive for each training session. Controls scenarios, data files, and execution of individual trainers, as opposed to the overall system.

POIC-DMS INTERFACE. Includes the representation of the interface between Operations Management Applications (OMA) and Payload Operations Ground Applications (POGA), and high rate data interface to the POIC.

PTC-POIC LINK. Is the link that is used for exchanging all simulated C&T data between the PTC and POIC.

PAYLOAD STIMULATOR. Includes all stimulation of payloads stemming from the simulations of the core systems and the external environment of the payloads, and simulated or actual ground support equipment for stimulation of payload sensors and software simulations of payload sensor/effector interfaces.

GROUND SUPPORT EQUIPMENT (GSE) CONTROL. Includes the capabilities needed to interface to and control the GFE GSE that supports flight equivalent payload simulators.

INSTRUCTOR CONTROL AND MONITORING. Includes all operator interface for the simulation executives function such as control of the simulators, scenario control, introduction of anomalies, and running and controlling each training session.

TRAINING SESSION MANAGEMENT. Includes the system controller, the unifying executive, and system configuration. Performs many functions off line in non real time.

OPERATOR CONTROL AND MONITORING. Includes all operator interface for the training session management functions such as system start up, system control, system logging, and system monitoring.

CONFIGURATION & SETUP. Subfunctions under the Training Session Management (system executive) function. Includes all capabilities that are needed to perform configuration management and setup of the trainers.

TRAINING ANALYSIS. Includes all capabilities that are needed to evaluate student performance and progress, and capabilities for evaluating the effectiveness of the training process. Also supports analysis of crew procedure execution results and timeline execution results.

TRAINING INFORMATION MANAGEMENT. Includes the capabilities needed to compile and maintain student records and training schedules.

POIC PERSONNEL INTERFACE REPRESENTATION. Includes the POIC consoles that will be part of the PTC training capability, and the software to make the consoles work - the Payload Operations Ground Applications (POGA). POGA is a subset of the OMS software. This may be eliminated from SCS by placing the consoles in the POIC. Some SCS support for this would still be required, no matter where the POIC consoles are place.

PTC EXTERNAL INTERFACES. Includes links to the Mission Planning System (MPS), SSIS Network, TMIS, and other information systems.

AUDIO/VIDEO SYSTEMS REPRESENTATION. Includes onboard audio/video, verbal communication between PTC and POIC, and PTC communication between instructors and students.

PRIMARY INSTRUCTIONAL DELIVERY. Includes classroom, CBT, onboard, and refresher training.

SIMULATOR, SCENARIO, AND DATA BASE DEVELOPMENT. Includes the capabilities for requirements analysis, coding, unit test, data base development, database maintenance, scenario development, simulator development, and sustaining engineering.

DEVELOPER INTERFACE. Includes the developer workstations, associated peripherals, and other interfaces with SCS for developing simulators, scenarios, and instructional materials.

CREW INTERFACE PROTOTYPING. Includes the developer's interface to SCS for developing representations of actual or virtual C&D panels, MPACs, and the ECWS.

INTEGRATE & TEST SIMULATOR. Includes I&T of simulation models, insuring transportability, and finding errors.

Each of the top level designs has been developed to accommodate the SCS requirements (functions). The explicit allocation of SCS functions to system components is tabulated for the six SCS integrated designs presented in Section 6.0.

As part of our Task 5 effort, we will compare the detailed conceptual designs and the above functions to ensure that, as the designs are developed to a more detailed level, they will continue to meet the required functionality. A matrix correlating the SCS functions with the SCS requirements is shown in Figure 1-1.

2.0 DESIGN EVALUATION CRITERIA

The design evaluation criteria developed as part of SCS Task 4 fall into eight categories. These criteria were utilized in Task 4, and will be utilized at a more detailed level in Task 5. These criteria are based on the SCS contractor team's experience and discussions with NASA. The evaluation criteria are:

1. RELIABILITY/MAINTAINABILITY. Reliability is measured by the Mean Time Between Failures (MTBF). Maintainability is measured by the Mean Time To Repair (MTTR). These two factors provide an excellent method for specifying system performance, and measuring system performance after the system is operational. For design evaluation purposes, the criteria will encompass the estimated operational reliability/maintainability of the overall hardware/software system.

2. EXPANDABILITY - SCALABILITY. Expandability is the ability of a particular design to accommodate adding new subsystems or systems. Scalability is the ability of a design to accommodate the expansion or addition of computing hardware or hardware capacity to existing subsystems. Both of these are measures of a design's ability to support the expansion of the SCS system to accommodate additional training load or the insertion of new, advanced technology.

3. COST. Cost of the SCS is a more complex issue than simply how much it will cost to build the system initially. COST TO BUILD is the first of the three evaluation factors for the SCS evaluation process. Due to the Space Station's long expected life, LIFE CYCLE COST is probably the most important factor to be considered under cost. A

Key:
- ● Totally Covers Requirement
- ◐ Partially Covers Requirement
- ○ Requirement Not Covered

SCS REQUIREMENTS	Training							Development													Ops Eval				
		P/L Crew			POIC			Support				Development						Integrate							
SCS FUNCTION	CBT	Part-Task/Combined	Consolidated	Integrated	Work-Station	POIC Interface	PTC Personnel	Training Planning	Setup	CBT Courseware Dev	Training Results Analysis	Simulator Req Analysis	Design Simulator	Implement Simulator	Test Simulator	Config Management	Maintenance	PTC Sim Integration	External Sim Integration	Final Integration of Sims	Ops Concept Definition	Crew Proc Dev/Test	Ops Cntr Proc Dev/Test	Timeline Verification	Demo/Evaluate SS Tech
DMS Representation		◐	◐	◐			◐																		
Core Systems Representation		◐	◐	◐			◐																		
C&T System Representation		◐	◐	◐			◐																		
Payload Representation		◐	◐	◐			◐																		
Crew Interface Representation		◐	◐	◐			◐																		
Simulation Executives		◐	◐	◐			◐																		
POIC-DMS Interface		◐	◐	◐	◐		◐																		
PTC-POIC Link		◐	◐	◐	◐	◐	◐																		
Payload Stimulator		◐	◐	◐			◐																		
GSE Control		◐	◐	◐			◐																		
Instructor Control and Monitoring		◐	◐	◐	◐		◐																		
Training Session Management	◐	◐	◐	◐	◐		◐																		
Operator Control & Monitoring		◐	◐	◐	◐		◐																		
Configuration and Setup		◐	◐	◐	◐		◐		●																
Training Analysis	◐	◐	◐	◐			◐				●														
Training Information Management	◐	◐	◐	◐			◐	◐		◐															
POIC Personnel I/F Representation					◐		◐																		
PTC External Interfaces						◐																			
Audio/Video System Representation		◐	◐	◐	◐		◐																		
Primary Instructional Delivery	◐						◐																		
Simulator, Scenario, & DB Dev.							◐	◐		◐		◐	◐	◐		●	◐				◐	◐	◐	◐	◐
Developer Interface							◐	◐		◐		◐	◐	◐			◐				◐	◐	◐	◐	◐
Crew Interface Prototyping							◐						◐	◐			◐								
Integrate & Test Simulators							◐								●			●	●	●					◐

Figure 1-1 SCS Specification vs. Function Cross Reference

third cost factor is SCHEDULE RISK. The SCHEDULE RISK factor involves dependencies on other parts of the overall Station program, and their effect on the SCS requirements and construction schedule. For example, if SSE models, DMS

Kits, or core system models are not available when development of the SCS requires them, the cost/effectiveness of the SCS development of specific designs will be impacted.

4.. COMPUTING HEADROOM. Computing headroom is an estimate of how much estimated headroom (unused and available computing capacity) a design will provide during an average training session.

5. HARDWARE/SOFTWARE COMPATIBILITY/STANDARDS. Compatibility and standards are a measure of a design's ability to make use of hardware and software that adhere to standards or are commercial off the shelf items. The more a design utilizes hardware and software that conforms to standards, the easier integration and upgrading will be, and the less technical risk a design presents.

6. RECONFIGURABILITY/MODULARITY. Reconfigurability is a measure of how well a design supports reallocation of and changes to system components to minimize the effects of a failure of a part of the system or to configure from one increment to the next. Modularity is a measure of how modular a design is. If a design is very modular, it will be easier for hardware to be substituted for software, and for software to be substituted for hardware. As technology changes, this could be a very important characteristic.

7. EASE OF OPERATION. Ease of operation is a measure of all aspects of a design's operability and Human Machine Interface (HMI). For example, does the design support running a training session from a single location, or must switches located in diverse locations be operated to begin a training session. For design evaluation purposes, this criterion will encompass the estimated ease of achieving efficient and effective system automation.

8. PERFORMANCE/FUNCTIONALITY VS. COST. A design may exceed all performance requirements, but be very expensive. Another design may exceed the basic required functionality, yet cost only about as much as a bare bones design which barely meets the system requirements.

The above evaluation criteria will be used as a basis for evaluating the SCS designs. Some evaluation criteria are more or less important than other criteria. The evaluation of designs should take this into account. The relative importance of the design evaluation criteria is given in Table 2-1.

Table 2-1 SCS Design Evaluation Weighting Factors

CRITERIA	WEIGHT
Reliability	Medium
Maintainability	Medium
Expandability	High
Scalability	Low
Cost	-----
- To Build Cost (H/W)	Medium
- To Build Cost (S/W)	High
- Life Cycle Cost	High
- Schedule Risk	High
Computing Headroom	Low
Hardware/Software Compatibility/Standards	High
Reconfigurability	High
Modularity	Medium
Ease of Operation	High
Performance/Functionality vs Cost	High

3.0 ARCHITECTURAL DIMENSIONS

To ensure that a broad spectrum of possible designs for the SCS was covered, it was necessary to define the possible relevant computer system architectural dimensions before the process of developing the designs began. Once these dimensions were established, and this list reviewed to ensure completeness, the dimensions could be used to guide the development of the top level designs. As the designs were developed, consideration was given to each of the dimensions and its possible effect on each family of designs. These dimensions proved useful not only at the top level, but at the more detailed level of trainer design as well. Following is a brief description of each of the five architectural dimensions applied to SCS.

CENTRALIZED VS. DISTRIBUTED. This dimension describes the distribution of host computers in the SCS. The range spans a single host computer to a fully distributed system with each application or function having its own host.

FAULT TOLERANCE. This dimension describes inherent architectural features or design provisions to cope with failures or errors in the system or its components. It includes both the ability of a design to endure faults, and the ability to recover from faults or failures.

SYSTEM COUPLING. This dimension describes the directness and degree to which each system component or application communicates with and affects other components or applications. The uniqueness and rigor of the format and synchronization of the data interchange are important factors.

CONCURRENCY. This dimension describes the ease and degree to which applications can execute concurrently. It covers, real-time and non real-time issues, single tasking vs. multitasking, and single CPU vs. parallel processing. It also covers shared media (memory, disk drives), and data integrity such as in a global database.

SYSTEM INTERFACES. This dimension describes the methods of interfacing various parts of the PTC/SCS systems with other SCS parts, with external systems, and the effect this has on the various designs. These include communications media and protocols for SCS communication and connections e.g. serial connections, parallel connections, buses, and networks.

4.0 CONCEPTUAL DESIGNS

A broad range of possible system designs was generated as part of this step of Task 4. A top-down approach was taken. The essential elements of the SCS which will be present in any implementation were explored along with various ways of implementing these elements. First, the major SCS elements were hierarchically decomposed into subelements. Next, the number of trainers were broken out. This process has yielded the SCS components shown in Figure 4-1. A brief description of these SCS components is shown on the page facing Figure 4-1.

- o SCS Control Environment
  - • Training Session Manager
    - - Overall SCS management, setup, configurations, data base management, status monitoring
  - • Instructor Stations
    - - Instructor controls the simulation, and can duplicate the crew console, introduce anomalies into the experiment, track student progress

- o CBT Stations
  - - Computer based training console, where courseware (with audio and video) resides on an optical disk. Used for introductory and refresher training.

- o Consolidated Increment Trainer
  - - Integrated US, ESA, and JEM Labs. It supports a full complement of experiments for a single increment.

- o Combined Trainer
  - - Independent US, ESA, and JEM Labs. Each Lab is capable of supporting a full complement of experiments for a single increment.

- o Attached Payload Trainer
  - - For payloads outside of Labs but attached to the Space Station. It is envisioned that attached payloads will have minimal crew interface and are operated principally through ground control.

- o Part Task Trainer A
  - - With DMS Kit
  - - Support a small number of experiments
  - - Four Part Task Trainer A

- o Part Task Trainer B
  - - Without DMS Kit
  - - Support a small number of experiments
  - - Five Part Task Trainer B

- o POIC Trainers
  - - Support ground control training for payload-specific operations.
  - - Seven POIC Trainers

- o Development & Test Environment
  - • Development Stations
    - - Workstations for simulation developers and training analysts
  - • Integration and Test Facility
    - - For integration and test of payload training models into the DMS and PTC environment
- o External PTC Interfaces
  - - PTC connections to other facilities

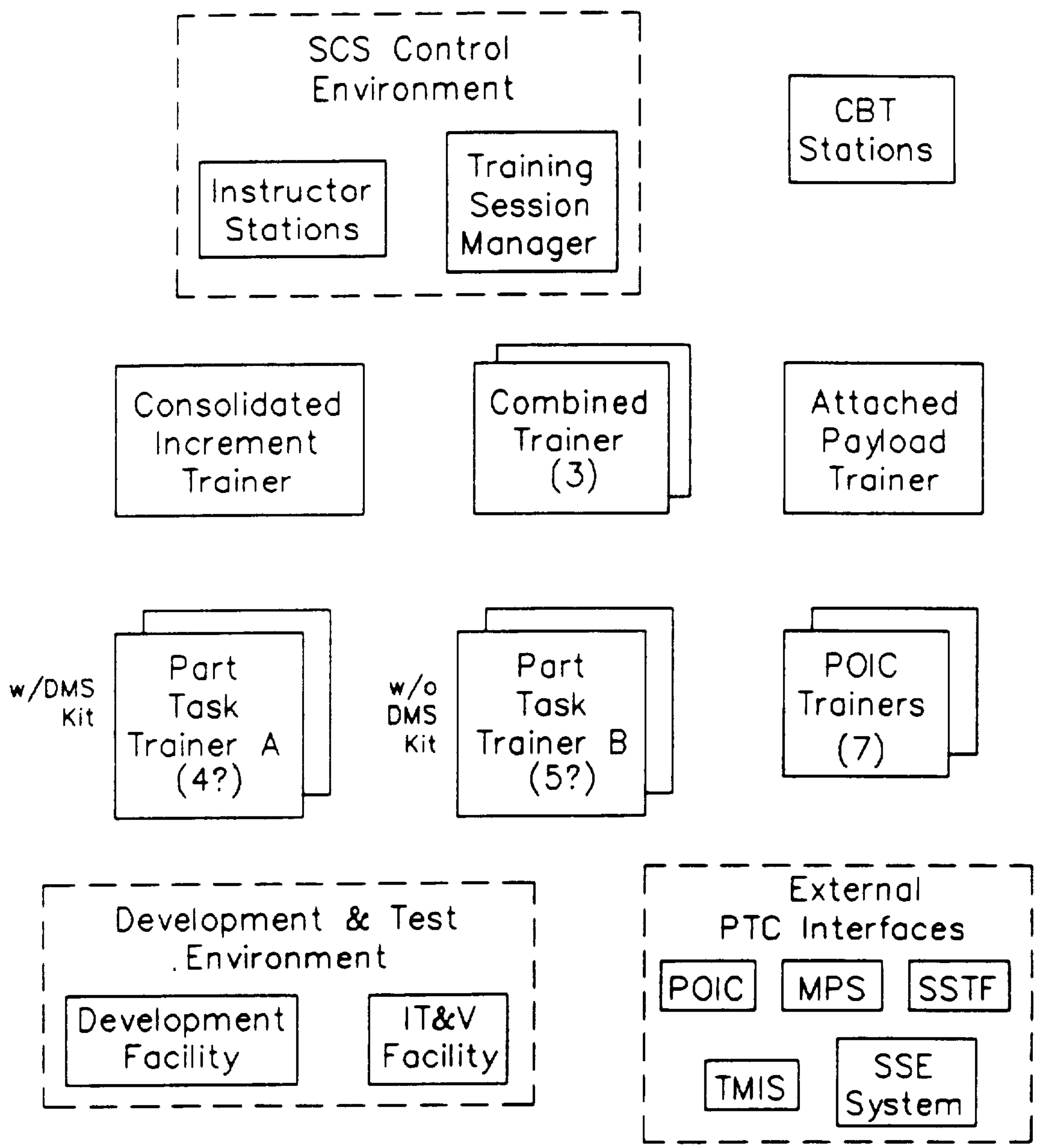


Figure 4-1 SCS Components

Next, top level system designs were developed. A spectrum of designs for the trainers were also developed. The designs presented, while not exhaustive, fully explore the range of architectural dimensions. The designs presented in this section can easily be used to down select to a useful smaller number of designs. Table 4-1 below summarizes the designs to be discussed. The designs numbered 1 - 6 are the different system level architectures, and the letters A - D indicate the different trainer level architectures.

TABLE 4-1 SCS Conceptual Designs

#	NAME	DESCRIPTION
1.	Monolithic Host	A single host for all SCS functions.
2.	Programmable Switch	A programmable switch connects hosts to trainers.
3.	Local Host Network	Local hosts connected via a network.
4.	Network Combined	Trainer hosts combined plus a network.
5.	Shared Host Network	Distributed network with shared hosts.
6.	Autonomous Trainers	One host per trainer, no network.
A.	DMS Kit	GFE DMS Kits are used.
B.	DMS Compatible	DMS components or DMS like components.
C.	PCTC based	DMS simulated in software on a host CPU.
D.	Distributed non-DMS	No DMS Kits, processors on a network.

The following pages graphically depict the designs for both the system (Figure 4-2 to 4-7), trainers (Figure 4-9 to 4-12), and development system (Figure 4-14). The system level and trainer level architectures underlying the various SCS conceptual designs are evaluated as they are introduced. The conceptual evaluations identify the advantages and disadvantages of each architecture. These features (advantages) and disadvantages of each design are shown on the page facing the design diagram for easy reference.

SCS TOP LEVEL DESIGN 1 (MONOLITHIC HOST)

Features

- o Single Host
- o Point to Point Connection to facilities
- o Central control
- o Homogeneous environment (single OS, CPU type)
- o Simpler Configuration
- o Easier Fault isolation

Disadvantages

- o Not fault tolerant/low reliability
- o Not modular/Hard to expand/Not flexible
- o Large Host required (mainframe)
- o Expensive

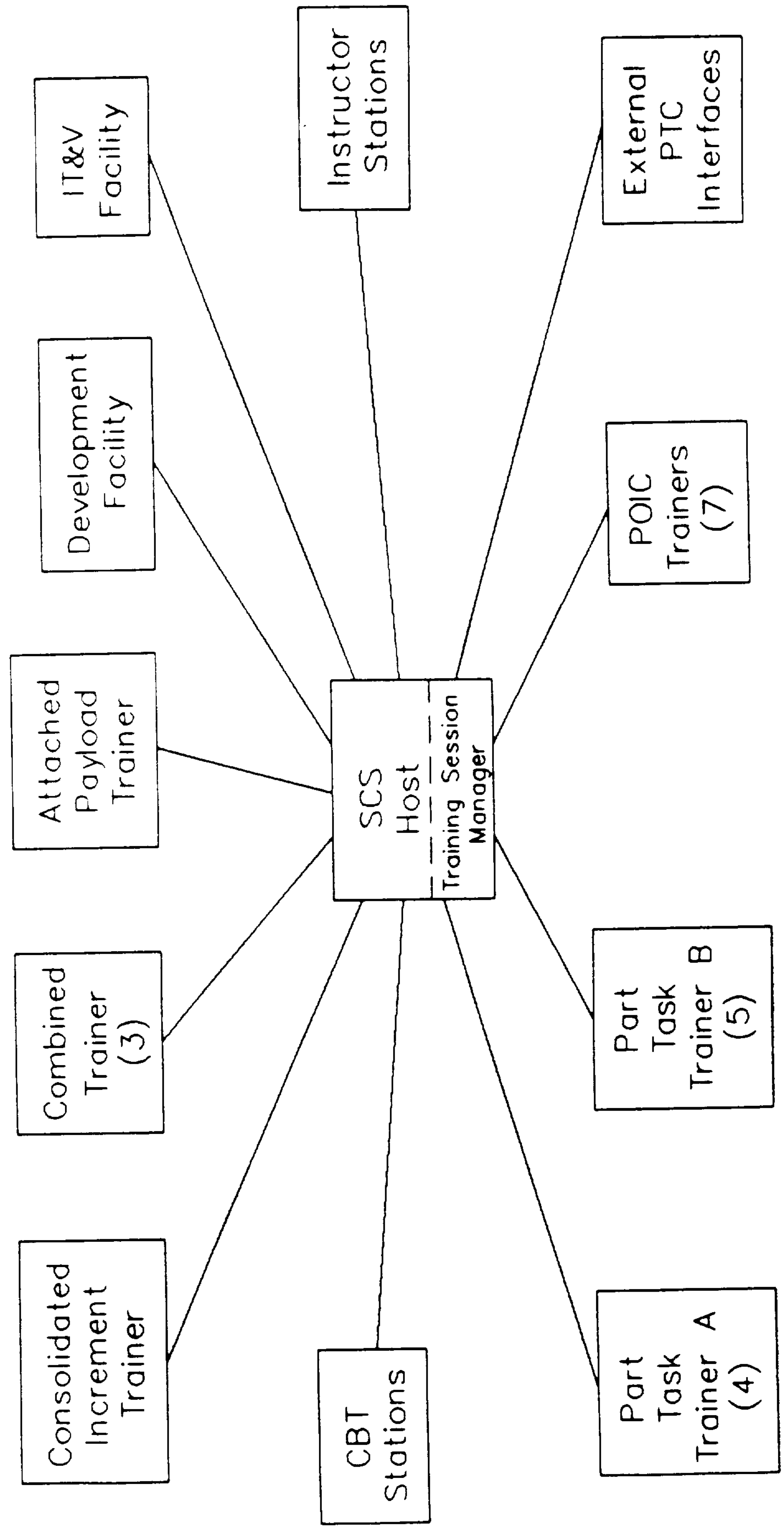


Figure 4-2 SCS Top Level Design 1 (Monolithic Host)

SCS TOP LEVEL DESIGN 2 (PROGRAMMABLE SWITCH WITH MULTIPLE HOSTS)

Features

- o More fault tolerant than Design 1 (reconfigure quickly)
- o In the event of a Host failure, the other Hosts can support all facilities with degraded performance
- o Centralized control
- o Point to point interface
- o Similar to SSTF architecture

Disadvantages

- o Large processors needed
- o Reliability low
- o Hard to expand (Must add additional Hosts)
- o Expensive
- o Communications between facilities must go through Hosts. No direct connection.
- o Complicated switching system - A network would be less complicated and have more functionality
- o Entire system goes down if switch fails
- o Degraded performance if one processor fails
- o System configuration tracking difficult
- o Requires two interface types to be switched; one for SIB interface to host, and one for non DMS trainer interface to host

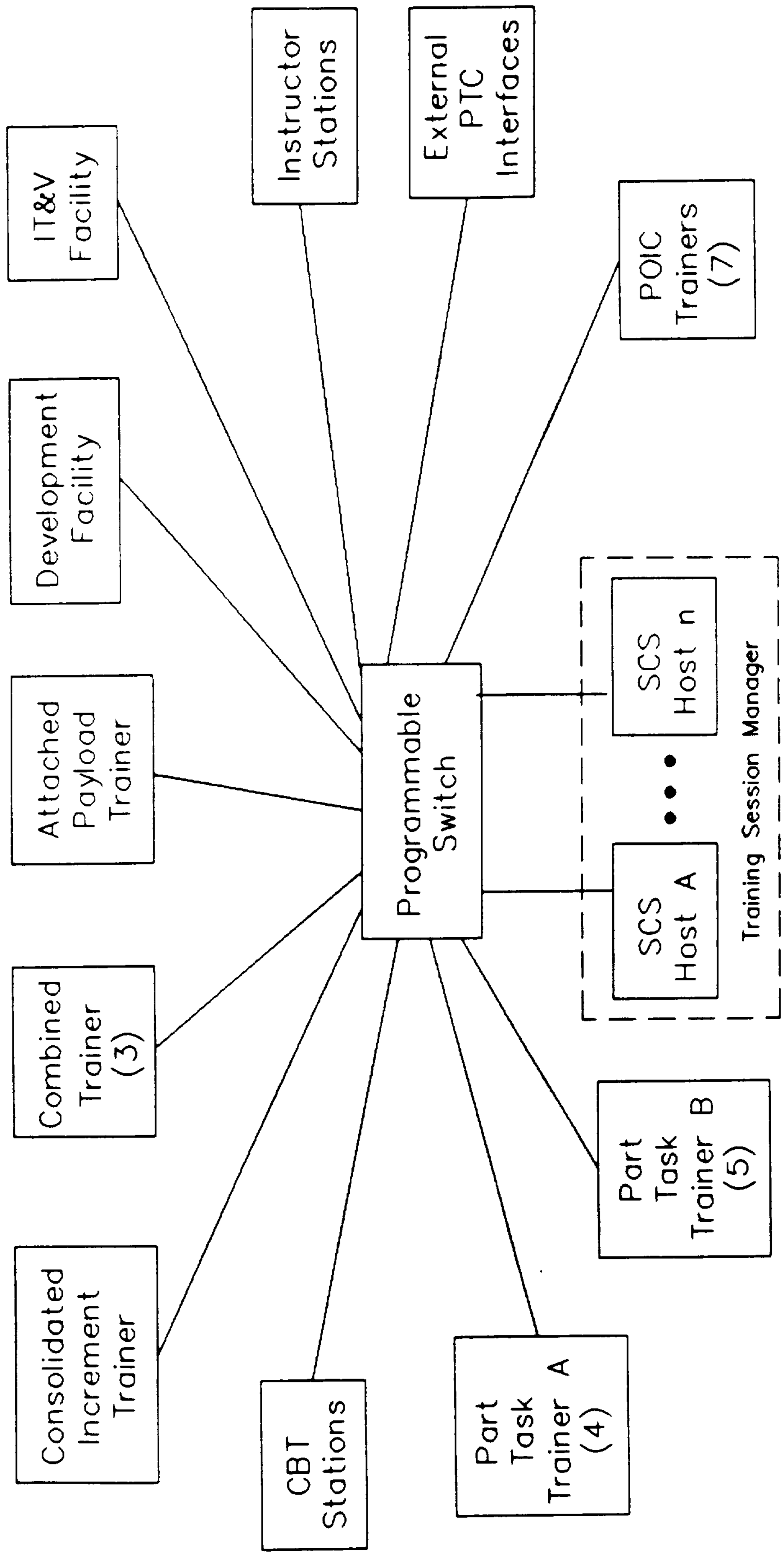


Figure 4-3 SCS Top Level Design 2 (Programmable Switch with Multiple Hosts)

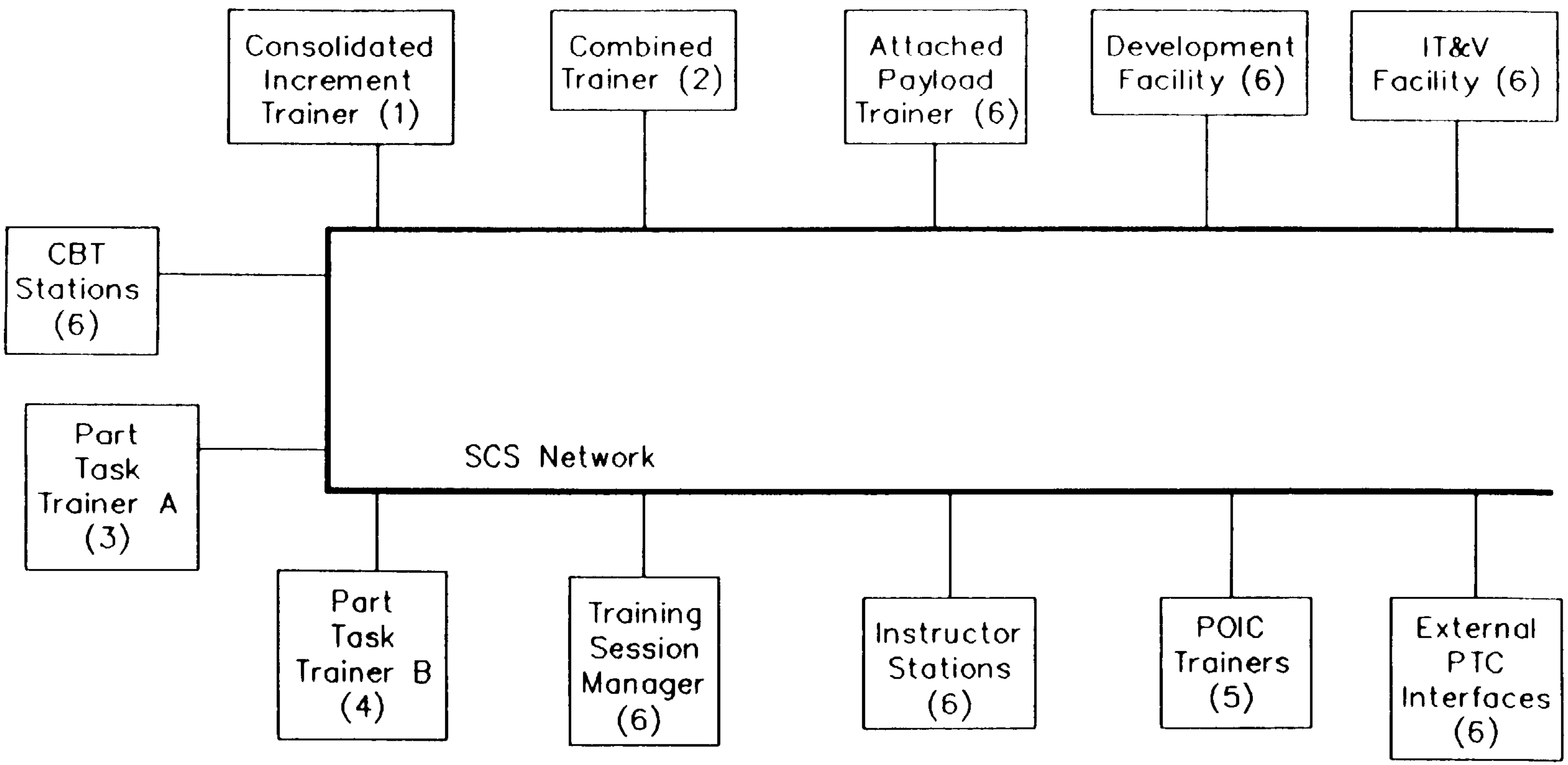
SCS TOP LEVEL DESIGN 3 (DISTRIBUTED NETWORK WITH LOCAL HOSTS)

Features

- o Unifying network
- o Each facility has dedicated Host
- o Training Session Manager provides a centralized control, status monitoring, and keeps track of system configuration
- o Communication between facilities quick and convenient
- o Distributed system/modular/flexible
- o Reliable/Maintainable (Can maintain part of the system without taking entire system down)
- o Direction of Advanced Technology
- o Technology Insertion Easier
- o Could have redundant network backbone for increased fault tolerance

Disadvantages

- o High network traffic
- o Large, but limited network bandwidth



NOTES:
(1) Integrated US, ESA, and JEM Labs with a single Host
(2) Independent US, ESA, and JEM Labs with separate Hosts
(3) Four Part Task Trainers with DMS Kits and separate Hosts
(4) Five Part Task Trainers without DMS Kits and separate Hosts
(5) Seven POIC Trainers with separate Hosts
(6) Dedicated Host

Figure 4-4 SCS Top Level Design 3 (Distributed Network with Local Hosts)

SCS TOP LEVEL DESIGN 4 (DISTRIBUTED NETWORK WITH LOCAL HOSTS AND COMBINED TRAINING COMPONENTS)

Features

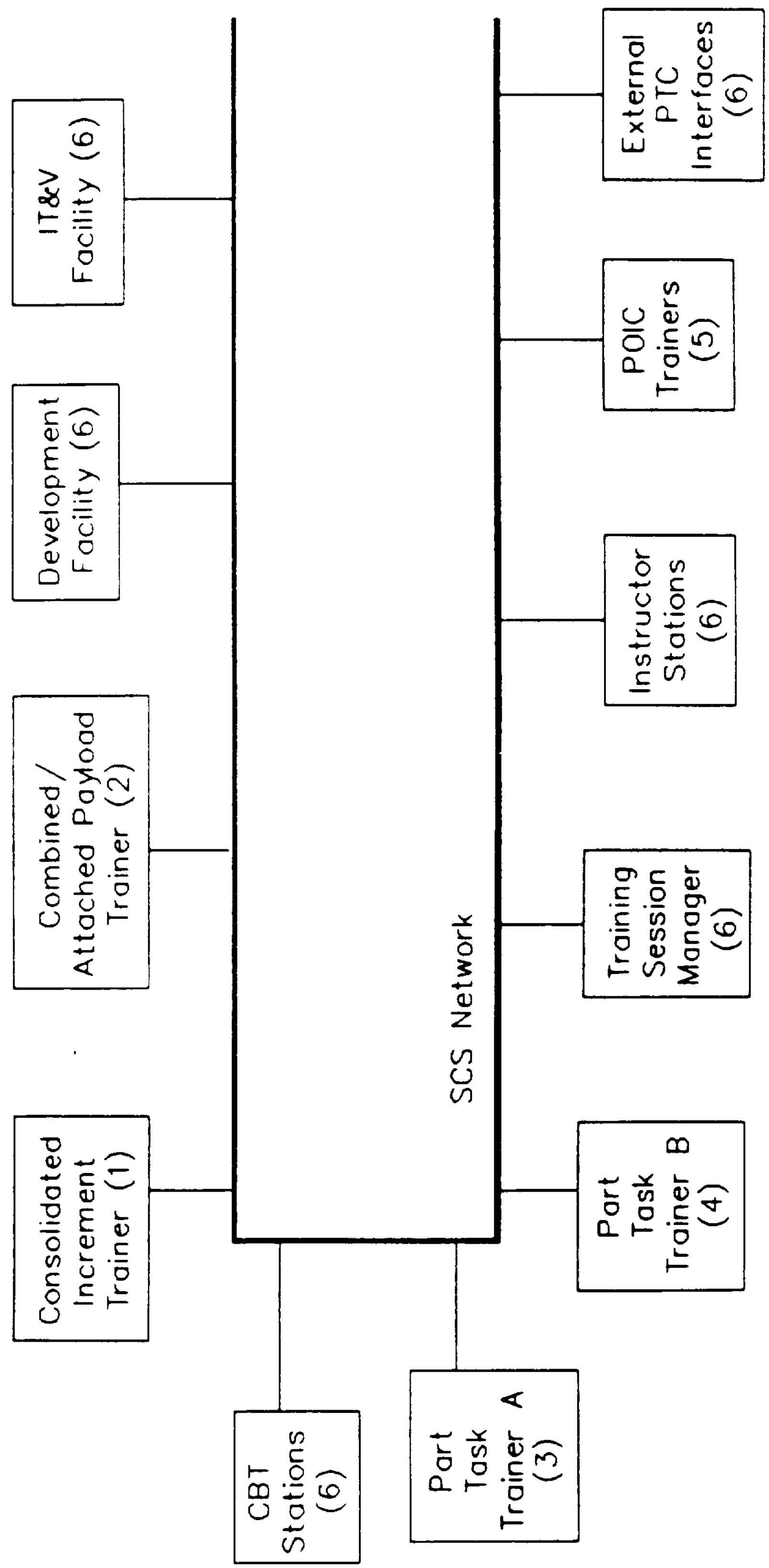
- o Similar to Top Level Design 3
- o The Combined and the Attached Payload Trainers are merged into the same facility
- o Cost savings
- o Greater integration between facilities

Option

- o Combine two or more Part-Task Trainers such that the host and possibly the SIB are shared between them.

Disadvantages

- o Difficult to perform Attached Payload or Combined Training independently. Could have resource conflicts.



NOTES:
(1) Integrated US, ESA, and JEM Labs with a single Host
(2) Independent US, ESA, and JEM Labs with separate Hosts, Attached Payload and US Lab Trainers combined
(3) Four Part Task Trainers with DMS Kits and separate Hosts
(4) Five Part Task Trainers without DMS Kits and separate Hosts
(5) Seven POIC Trainers with separate Hosts
(6) Dedicated Host

Figure 4-5 SCS Top Level Design 4 (Distributed Network with Combined Subsystems)

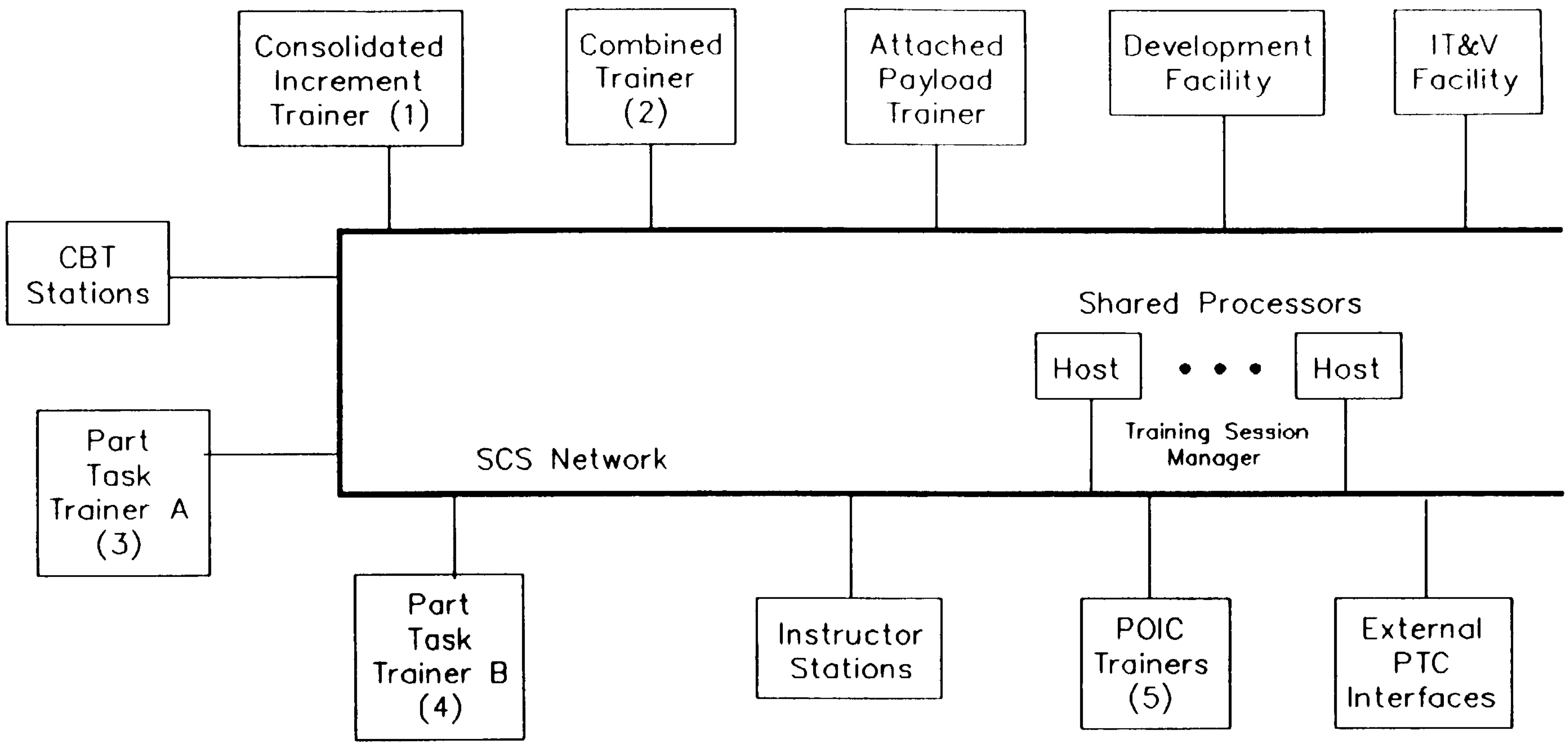
SCS TOP LEVEL DESIGN 5 (DISTRIBUTED NETWORK WITH SHARED HOSTS)

Features

- o Similar to SCS Top Level Design 3
- o Attach multiple Hosts to network - Eliminate dedicated trainer Hosts
- o Network Hosts could share processing load and be quickly reconfigured in the event of a failure
- o Connectivity to the SIB is slightly complicated in this design but could be overcome with Host interface (Idea expanded in SCS Integrated Conceptual Design 5-A)
- o Allows resource sharing
- o Increases fault tolerance

Disadvantages

- o Increased complexity in system communications and control
- o Potential network bandwidth constraints due to increased network traffic



NOTES: No dedicated Host processor in each facility

(1) Integrated US, ESA, and JEM Labs
(2) Independent US, ESA, and JEM Labs
(3) Four Part Task Trainers with DMS Kits
(4) Five Part Task Trainers without DMS Kits
(5) Seven POIC Trainers

Figure 4-6 SCS Top Level Design 5 (Distributed Network with Shared Hosts)

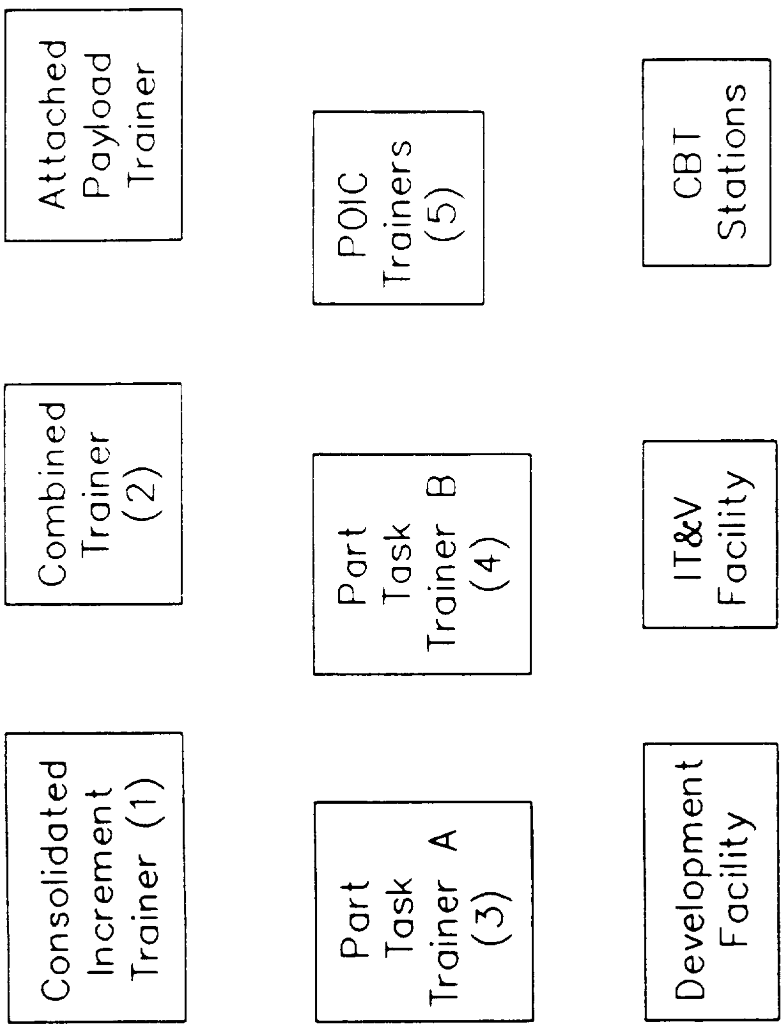
SCS TOP LEVEL DESIGN 6 (AUTONOMOUS TRAINERS- NO NETWORK)

Features

- o Each trainer has dedicated Host
- o Inexpensive - No network
- o Can communicate with other trainers via "sneaker net", i.e. tapes or disks are hand-carried between trainers.
- o Modular
- o Model for computing systems in the past
- o Training Session Manager functions performed independently by each Trainer

Disadvantages

- o No centralized control, status monitoring
- o Some trainers (POIC and PTT) may need resources from other trainers
- o Poor integration- leads to uncoordinated efforts
- o Data exchange via tapes carried from one system to another slow



Notes:
(1) Integrated US, ESA, and JEM Labs
(2) Independent US, ESA, and JEM Labs
(3) Four Part Task Trainers with DMS Kits
(4) Five Part Task Trainers without DMS Kits
(5) Seven POIC Trainers

Figure 4-7 SCS Top Level Design 6 (Autonomous Trainers - No Network)

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Trainer Designs

The trainer designs address the components as shown in Figure 4-8. The designs focus on all the SCS trainers (Consolidated, Combined , Attached Payload, and Part Task), and the IT&V Facility. Which components are addressed by which designs is shown by the two different shadings on the legend. All these components have similar functional requirements. It would simplify SCS design and maintenance for all the trainers to have similar designs (architectures). Modularity of trainer design would enhance maintainability. The four trainer designs presented can all be applied to any top level design.

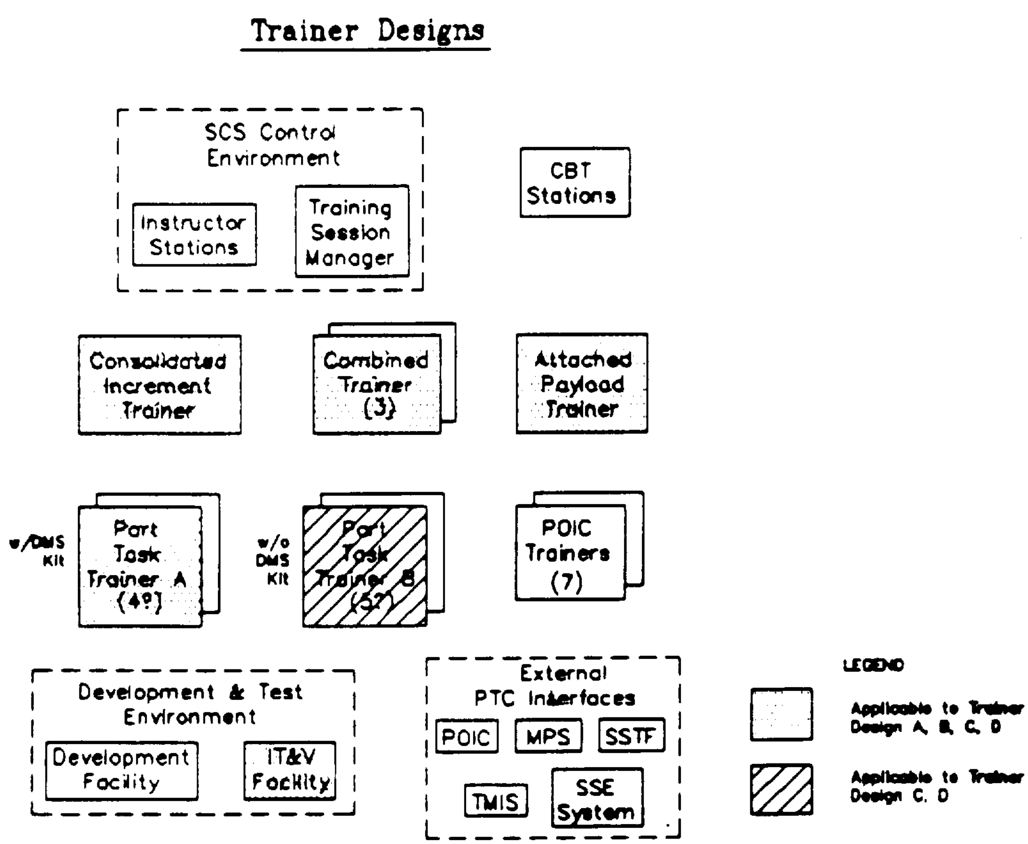

Figure 4-8 SCS Components Addressed by Trainer Designs

TRAINER DESIGN A (DMS Kit Approach)

Features

- o SIB, DMS Kit
- o Dedicated or possibly shared Host
- o Closely follows architecture envisioned by SSE as Development, Integration, and Test environment
- o DMS Kit includes crew interface (MPAC, ECWS)
- o Quite similar to SSTF architecture
- o Payload attached to Payload LAN, Local Bus, MDM, SDP, or run on Host with direct attachement to payload
- o Core system H/W largely included in DMS Kit - Core system S/W (models) are GFE
- o Closely models the SS DMS architecture (Host and SIB are additional)
- o The Instructor Station could be directly attached to the trainer Host

SIB:

- o SIB can substitute for or replace any DMS node - SDP, MDM, TGU, etc.
- o The SIB could reduce amount of DMS H/W required
- o SIB interfaces to all DMS internal buses and networks - can control DMS devices, monitor bus traffic

Disadvantages

- o SIB is expensive - Much of SIB functionality may not be needed or can be accomplished another way
- o DMS H/W and S/W may not be available when needed
- o DMS Kit expensive
- o SIB is single point of failure for trainer since all communications from Host pass through it
- o Host and DMS Network Operating System (NOS) may be different and have different processor architectures

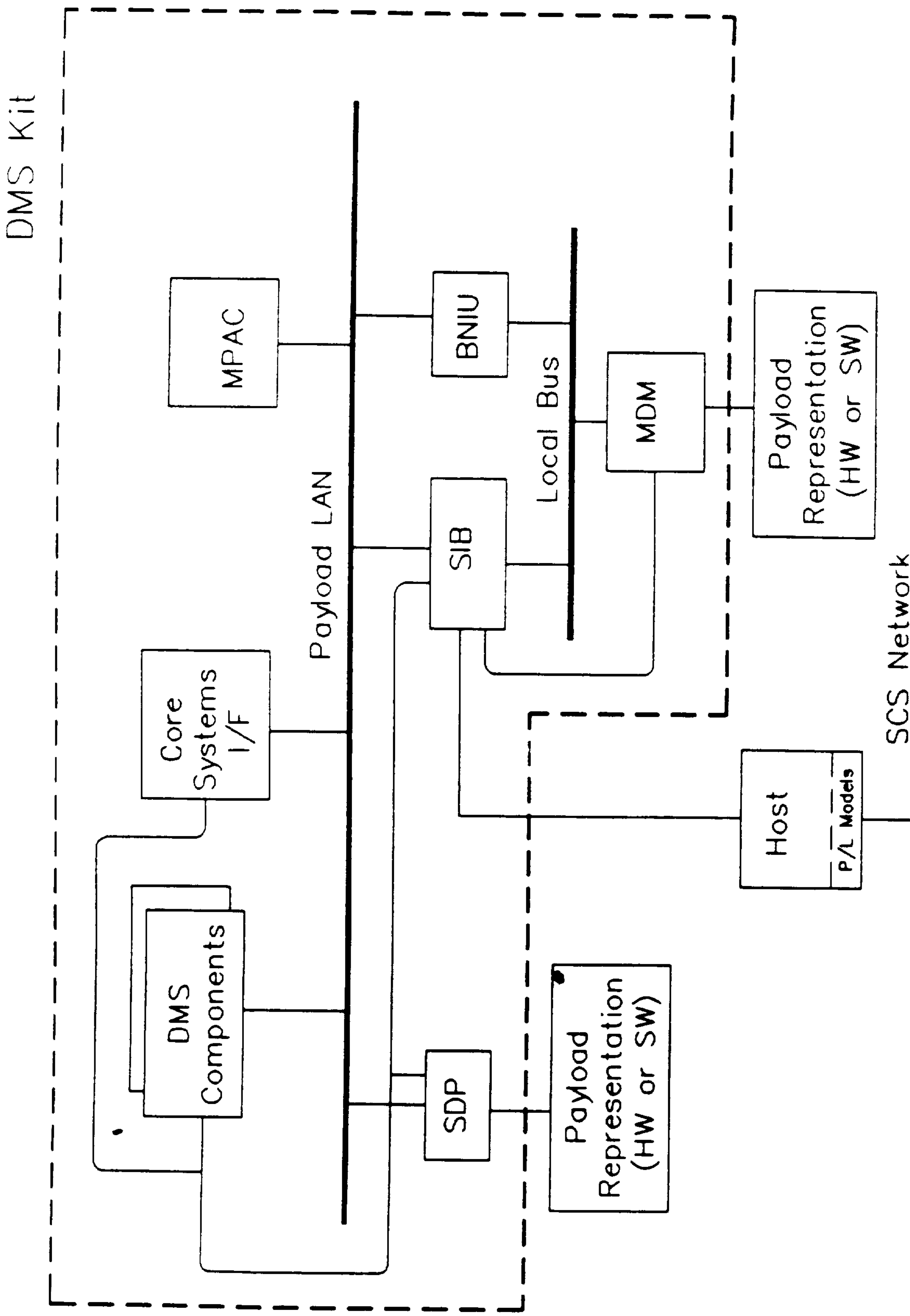

Figure 4-9 SCS Trainer Design A (DMS Kit Approach)

TRAINER DESIGN B (DMS Compatible Approach)

Features

- o No SIB
- o Host is implemented with a SDP from the DMS Kit (386 based processor- up to 8 MIPs of processing capability)
- o Commonality of OS, networks, Application I/Fs
- o Less expensive than Trainer Design A
- o SDP has connection to SCS network through Multibus II I/F
- o Could use 486 based processor (or some other compute server) if more computational power needed for Host

Or:

- o Connect Non-DMS Host to Payload LAN with NIU card set for additional computational power
- o Use SSE and DMS services fully for experiment model development (rich environment)
- o Very similar to SS DMS architecture

Disadvantages

- o No SIB functionality - SIB functionality for fault insertion/malfunction control will be more difficult
- o SDP might not be able to handle all simulation executive tasks
- o DMS Kits may not be available when needed
- o Functional simulations of DMS software developed by the DMS contractor if used could require the SIB

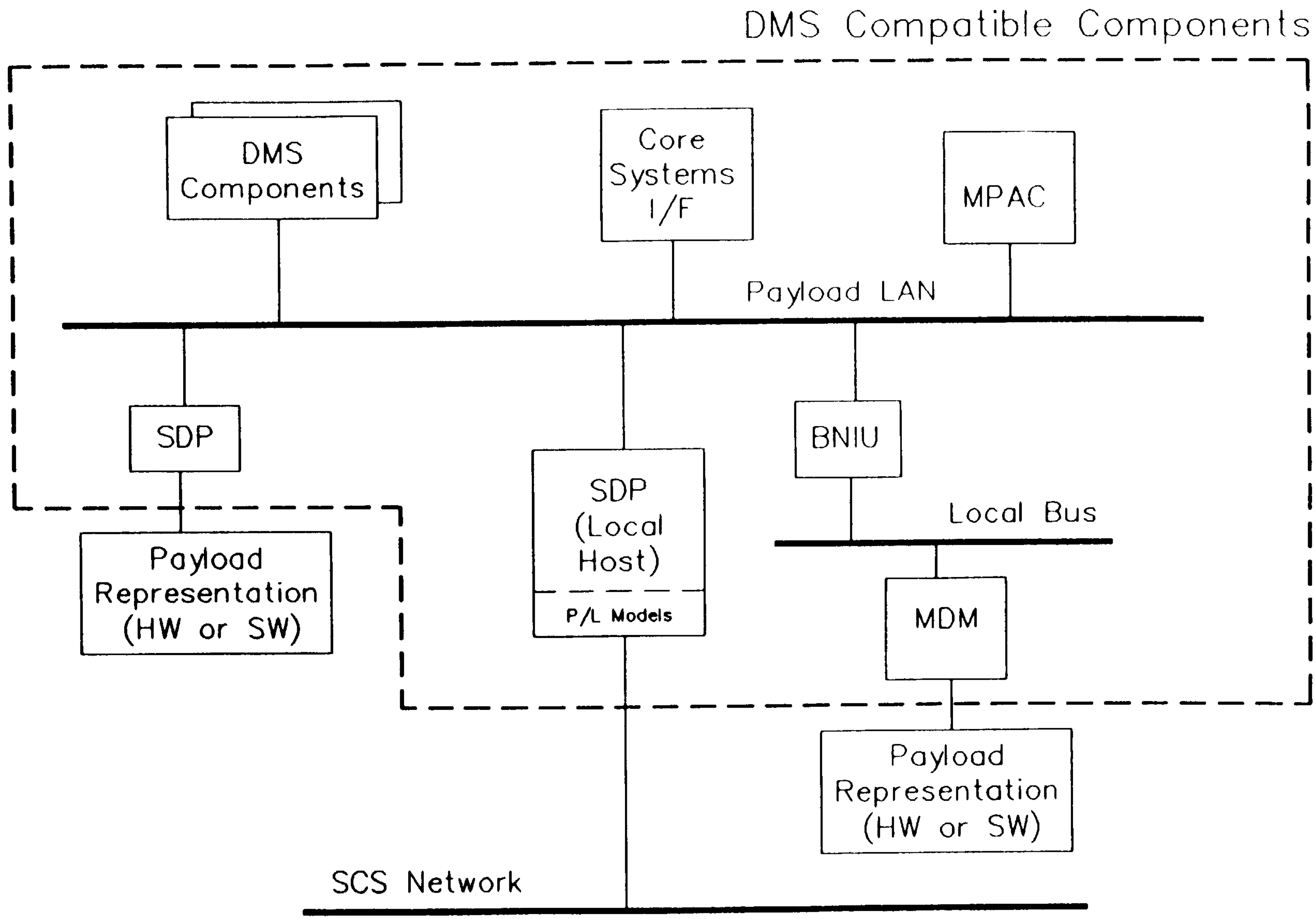

Figure 4-10 SCS Trainer Design B (DMS Compatible Approach)

TRAINER DESIGN C (PCTC-Based Approach)

Features

- Monolithic Trainer Host
- No DMS H/W, No SIB
- H/W cost much less than Trainer Design A,B
- DMS software could be used with some modification

Or:

- Develop functional simulation of DMS including DMS services and OMA (these models could be available from SSE)
- Since DMS developed with SSE tools, the task of modifying it for use with non-DMS H/W would be easier than if traditional development methodologies were used
- Midrange processor required
- Single processor, multitasking OS (could use DMS OS)

Disadvantages

- Developing a simulation of DMS is a big job unless SSE FSIM model is used or modified
- If actual DMS S/W is used, modifying it for non-DMS H/W is a significant job, but less effort than modeling the DMS from scratch
- Not fault tolerant- However, the other designs are not better in this respect
- S/W cost greater than Trainer Design A,B - This cost must be balanced against the lower H/W cost
- Hardware interfacing required
- Extreme care would be required to assure portability to the SSTF.

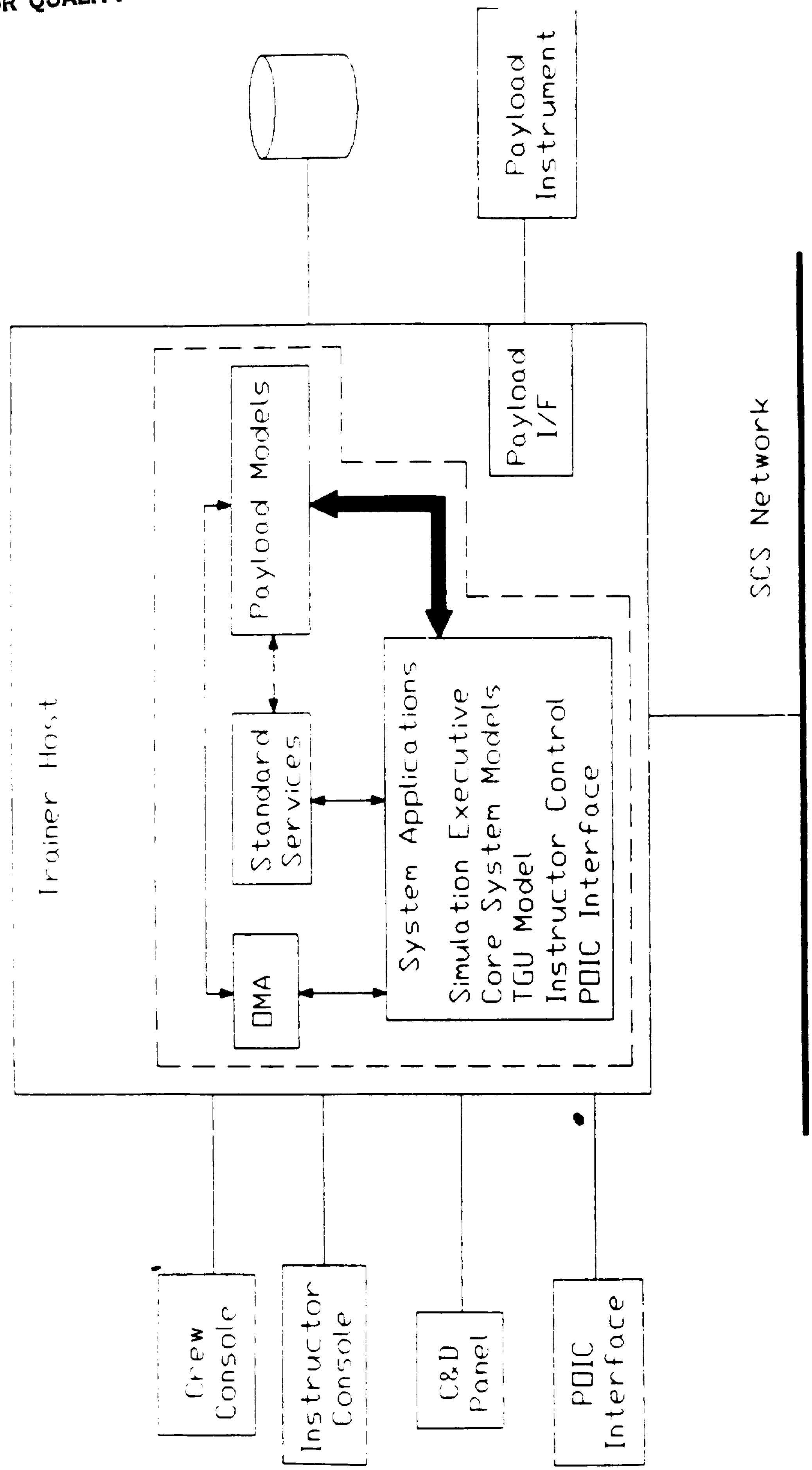

Figure 4-11 SCS Trainer Design C (PCTC- Based Approach)

TRAINER DESIGN D (Distributed Non-DMS)

Features

- o Similar to Trainer Design C, except that distributed processors are used instead of one centralized processor
- o More fault tolerant than Trainer Design C
- o No DMS Kit, No SIB
- o Processors are small (could be PCs)
- o DMS S/W might be usable with modifications

Or:

- o DMS FSIM used

Or:

- o Develop DMS functional simulation
- o H/W is inexpensive
- o Modular
- o Easy to add capability

Disadvantages

- o DMS simulation is a significant job
- o Application to Application I/Fs are more complicated over a network (standard networks can handle this problem)
- o Extreme care would be required to assure portability to the SSTF.

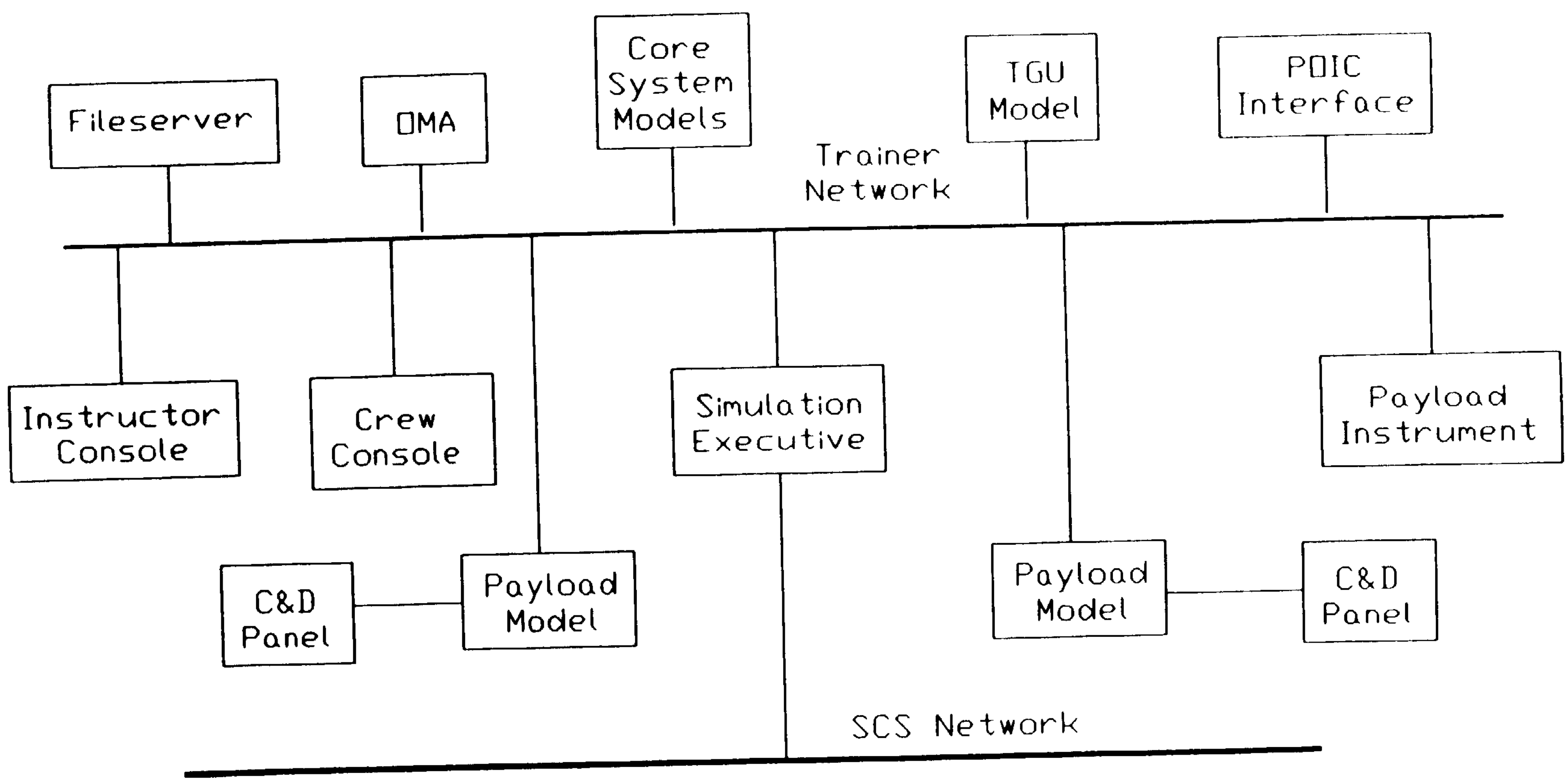

Figure 4-12 SCS Trainer Design D (Distributed Non-DMS Approach)

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Development Facility

There are several possible designs for the SCS Development Facility. However, since it is clear that the SCS Development Facility must be compatible with the SSE Software Production Facility (SPF), only one of the options for the SCS Simulation Development Facility is presented (Figure 4-14). The Development Facility design addresses the component shown in Figure 4-13.

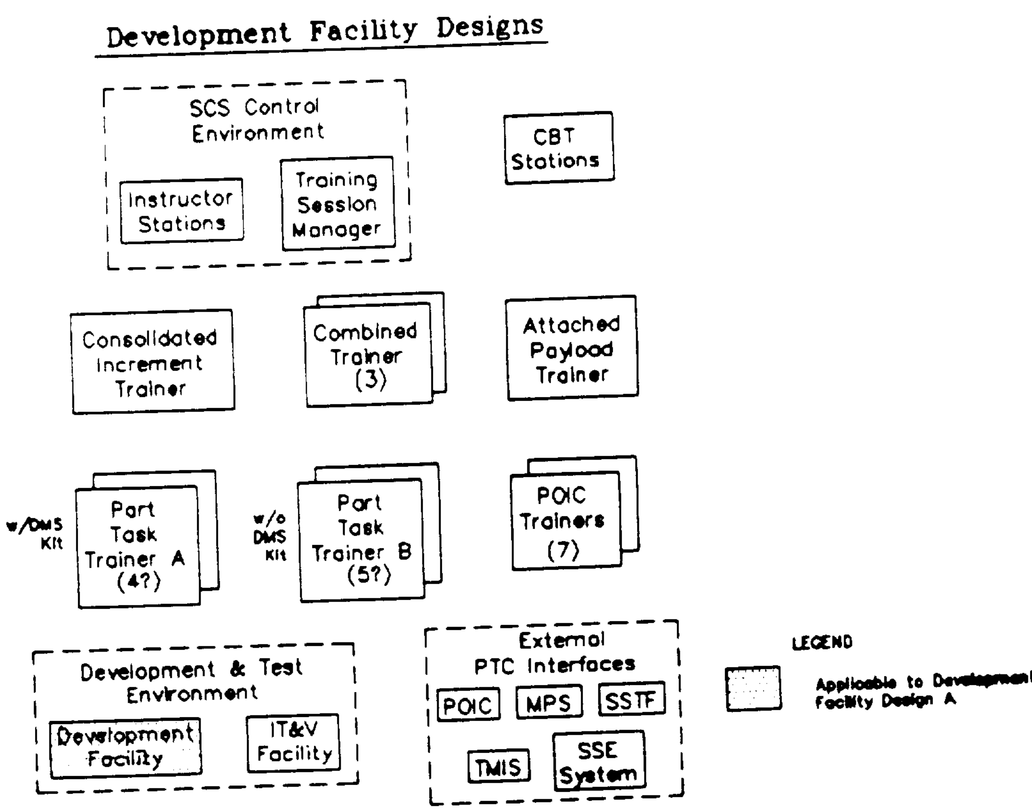


Figure 4-13 SCS Components Addressed by Development Facility Design

DEVELOPMENT FACILITY DESIGN A (SPF Compatible)

Features

- o Centralized Host (SPF) for simulation development.
- o Simulation development host could be local or remote Software Production Facility (SPF).
- o Two Hosts provide redundancy and increase fault tolerance
- o Traditional timesharing computer system
- o Developer stations are intelligent workstations

Options

- o Could have workstations directly attached to Hosts instead of through network
- o Could have only one Host

Disadvantages

- o Large Host(s) for development is expensive

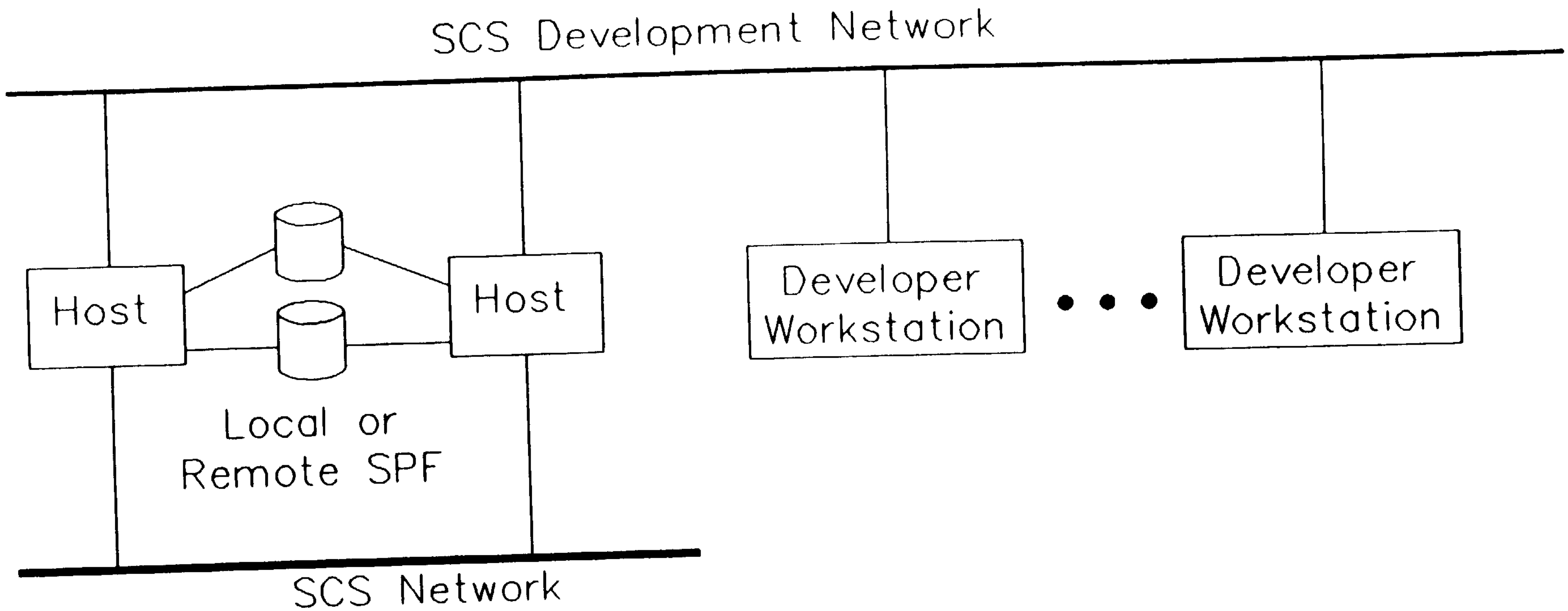


Figure 4-14 SCS Development Facility Design A (SPF Compatible)

Design Considerations

The range of designs was constrained by selecting the most fundamentally different designs and making sure that, at least at face value, the designs were feasible solutions to the set of SCS requirements. Three basic architectures emerged as viable SCS systems: (a) switched shared host systems (top-level design # 2), (b) networked shared host systems (top-level design # 5), and (c) networked local host systems (top-level designs # 3 & # 4). Other hybrid architectures could be formed by combining the networked shared host for the more global SCS functions with the networked local host for trainer level functions.

Additional architectural possibilities were identified as less flexible, but none-the-less viable, system designs. The monolithic host architecture (top-level design # 1) and the autonomous trainer architecture (top-level design # 6) are examples. Other system architectures exist as variations of the three basic architectures. These variations arise at two levels - system segmentation and system implementation. The system segmentation level can be used to separate the system into partitions with different basic architectures in each. The implementation level can be used to distinguish among different instances of a basic system structure. For example, the media, format, and topology of an interconnection scheme may form distinct variations of a networked system architecture.

The designs presented represent both the range of fundamental architectures and the role of certain variations within these architectures. By combining the six top level system designs (Designs 1-6) with the four trainer designs (Designs A-D), a resulting set of twenty four candidate conceptual designs is formed. Six of these consolidated designs are discussed further and in more detail in section 6.0 of this report.

5.0 DESIGN EVALUATION

The generation of feasible SCS conceptual designs has been accompanied by an on-going evaluation of each design. The evaluations initially stemmed from the compilation of SCS functional requirements used to guide the development of each design. Designs were systematically compared in respect to how their constituent components would be responsible for the 24 basic SCS functions (system requirements) delineated earlier. The allocations of SCS functions across the designs' various components served to isolate the functionally significant differences distinguishing these designs.

The SCS design experience to date has yielded an understanding of the architectural requirements such that the selection of candidate designs can be grounded on definite design guidelines or constraints. In order to ensure that the candidate set approached an optimal design solution, three guidelines were exercised when selecting designs from the range defined in Section 4.0. These design guidelines reinforced the architectural characteristics which are important to optimizing the functional capabilities and performance of any SCS design. The guidelines are:

1) Processing separation of real-time simulation from non real-time training/support functions.

2) Processing separation between different concurrent training sessions.

3) If trainers are based on DMS components, they should utilize a SIB.

For purposes of this design selection, the first guideline - the separation of real-time from non real-time processing - has been adopted as an SCS design constraint affecting all candidate designs. The other two were utilized as guidelines.

6.0 RECOMMENDED DESIGNS

Six of the possible twenty-four SCS conceptual designs were selected on the basis discussed above in Design Evaluation, and for reasons discussed below to be considered further and graphically depicted. These recommended candidate designs appear to be the most feasible and distinct designs available from the study's defined architectures and associated variations. The number and letter trace the design back to the system and trainer design designations used in Section 4.0, e.g. SCS Integrated Conceptual Design 3-A combines system design 3 with trainer design A. For convenience, the pictures of the six designs are contained together as a package in Appendix A. Also provided in Appendix A is the comparison of design to requirements (functions). These are shown as function allocation matrices for the six complete designs. The matrix shown facing each design indicates which potential SCS components comprise the design, and which SCS functions are allocated to each component.

The SCS designs represented at this conceptual level are composed of hardware drawn from a global set of possible system components. These generic system components make up the columns of the function allocation matrix used to characterize each conceptual design. If a generic component is not used in a given SCS design, no SCS functions will be entered in that column. Further, the name of the component appearing as the column heading will be grayed out. The set of possible generic components includes four distinct general purpose (GP) hosts. SCS designs vary, in part, by the different levels of host computers across which the SCS functions are distributed. By design objective, each host computer primarily supports either real-time simulation applications or non-real-time support and systems applications, but not both. Other SCS system components encompass actual and emulated payload instruments, basic DMS components and the associated simulation interface buffer (SIB), audio and video sources, device(s) for stimulating payloads, types of alphanumeric/graphics user terminals, and backbone components such as a programmable data switch or network system interconnecting an SCS. The generic components are described briefly in the following paragraphs.

- In an SCS design, the central host(s) assume the system executive, or training system management function, and other non-real-time functions across the

SCS. This includes configuration and setup, development, and overall training session control. (In a single level host design -- not represented here -- the central hosts(s) would also support real-time simulation applications.)

- The simulation host(s) and any lower level hosts support trainer operations including real-time simulation functions. The simulation host is responsible for multiple trainers. If there is no trainer or lower level host included in the design, the simulation host can assume (by multiplexing) the real-time simulation functions across trainers.

- The trainer host(s) are dedicated to a single trainer. Unless lower level host(s) are included in the trainer design, the trainer host(s) support real-time payload, space station, and ground simulation.

- Payload simulation functions are assumed exclusively by the payload host(s) when they are present. The payload host may be implemented as a clone of the flight equivalent SDP in order to interface with DMS related components and be capable of running program code derived from flight software. The host may also assume (by multiplexing) simulation function across multiple payloads.

- Payload instruments (as equivalent or prototype flight hardware and software) may, when available, be incorporated to meet desired high fidelity training requirements.

- A C&D emulator may be used in lieu of the flight equivalent article. The device is incorporated in the trainer design to emulate the control and display (C&D) panel of the payload instrument. The emulator may be based on a general purpose computer multiplexed to multiple dedicated or virtual C&D panels. Representation of payload hardware and operation other than the C&D panel, and/or MPAC interface, may be emulated as desirable.

- For actual payloads and possibly emulated payloads embedded in a flight equivalent DMS environment, a trainer is supported with basic DMS configurations of the DMS MDM with its EDP, a separate DMS SDP, DMS MPACs (fixed and portable), DMS payload (P/L) network, and the DMS TGU or equivalent time generation subsystem.

- When the DMS configuration is provided as a DMS kit, it will be integrated around the SSE simulation interface buffer (SIB). The SIB will define and implement a single interface between an SCS general purpose host and the DMS kit components.

- Audio and video systems will support payload simulation, SSF environment simulation, and ground communications simulation, as needed, and provide SCS intra-facility communications for training session operations. Source generation and storage capabilities for CCTV, computer generated imagery, and digitized audio/video may be implemented with host and peripheral devices.

• Payload (P/L) stimulation hardware (H/W) includes analog and digital interface devices to stimulate individual payloads. When DMS components are not used, functions of the MDM may be implemented in hardware and simulation software. For flight equivalent articles, stimulation may involve real-time control of associated GSE and physical services necessary to sustain and operate payloads.

• General purpose (GP Workstations) may be used in lieu of flight equivalent fixed/portable MPACs, as in a DMS kit, to simulate flight crew stations in an SCS design. Workstations with graphic capabilities may support standalone applications implementing the crew interface. Applications on the workstation may also implement instructor control and monitoring functions allowing it to serve as the instructor station.

• General purpose (GP) computer terminals with host/network communications support may, similarly, offer the alphanumeric/graphic display and input capabilities needed for crew station and instructor station implementations. Applications necessary to simulate the crew interface and manage instructor control and monitoring would be all host based.

• The programmable data switch(es) basically serve to tie trainers selectively to GP hosts. The ganged interconnection may be complex when, for example, a separate SIB interfaces each DMS trainer unit. Discrete switching may be used exclusively or in conjunction with networks. A patch panel to route high rate science data is treated as a data switch.

• The SCS network(s) link trainers, hosts, development facilities, and external communications facilities. Although networks are assumed to be baseband, the media, topology, and protocol features of the architectures are flexible. While duplication of the SSF's FDDI token ring may achieve design rigor, substitution in some SCS designs with, for example, an Ethernet backbone may prove both feasible and economical. The operating system and network management system will determine the ultimate use and performance of the network.

• The network bridges and gateways effect the interfaces between separate SCS network subsystems and those with external communications. Network routers may be included to facilitate system configuration, fault recovery, and load balancing. By design objective, transmission of real-time simulation data is dedicated to networks insulated from other networks carrying predominantly non-real-time data.

Following are descriptions and discussions of the six recommended designs shown in Appendix A.

I. SCS Integrated Conceptual Design 3-A

Integrates the Distributed Network Local Host architecture with the DMS Kit trainer design. The trainers perform all real-time simulation activities required to support payload training. The SIB may be used to replace DMS components, including the Time Generation Unit (TGU), Mass Storage Unit (MSU), Standard Data Processors (SDP), Bus Interface Adapters, Multiplexer/Demultiplexers (MDMs), and Multipurpose Application Consoles (MPACs).

The distributed network allows maximum flexibility for high speed communications between the SCS facilities or subsystems. Any facility can exchange data with any other facility using a single interface. The implementation of a single local trainer host for payload simulation executive functions is less complex from a system software viewpoint than implementing shared hosts at the PTC level. In addition, the use of shared hosts at the PTC level would require a complex switching interface for the connection of the SIB to the global shared host.

The use of the DMS Kit, including the SIB, is the SSE recommended approach to Space Station system development, integration, testing, and training by the Software Support Environment. It is also the approach favored by the SSTF development effort at JSC. The use of the DMS Kit helps guarantee a high level of fidelity for payload training. Flight equivalent Space Station systems and payloads are easily integrated into the trainer with the DMS Kit. Also, Core system functional simulations, software developed for the SSTF, and SSE developed software would be directly transportable to the PTC. Likewise, PTC developed experiment models would be more easily transportable to the SSTF if developed in a DMS Kit environment. The SIB offers a great deal of functionality, and could potentially replace some of the DMS components - a potential cost savings. The SIB also simplifies the implementation of some training requirements, like fault insertion. For additional information on the DMS Kit see the Prime Item Development Specification Data Management System Kits.

II. <u>SCS Integrated Conceptual Design 3/5-A</u>

This design integrates a combination of the Distributed Network Local Hosts and Distributed Network Shared Hosts architecture with the DMS Kit trainer design. Individual shared hosts are allocated to perform real-time or non real-time functions, but not both. The real-time shared hosts support a different training scenario for each trainer. The local hosts support real-time training functions specific to a particular trainer.

This design is somewhat similar to 3-A (# I) above, and shares many of the advantages discussed. By off loading the non real-time trainer functions on to a shared global host, the performance of the real-time trainer host is improved. The use of shared hosts for non real-time functions offers additional flexibility, increased fault tolerance, and allows more powerful, more cost effective hosts to be utilized than a design with only dedicated hosts.

III. <u>SCS Integrated Conceptual Design 4-B</u>

Integrates the Distributed Network with Local Hosts and Combined Training Components architecture with the DMS Compatible trainer design. The

Combined trainer is integrated with the Attached Payload trainer. The DMS trainer host is implemented on a SDP with no SIB.

This design utilizes a distributed network, like 3-A (# I) above. By combining two fully configured trainers - the Combined and the Attached Payload trainers - a substantial savings in equipment cost and possibly facility space can be obtained. In this configuration, a single trainer host (SDP) could be utilized for both trainers. Some of the DMS components, like the TGU and MSU, would not have to be duplicated. In addition, there are opportunities for further consolidation. The Part Task Trainers could also be combined such that a single host (SDP) could support multiple Part Task Trainers.

The trainer design is similar to 3-A (# I) above except that the SIB is eliminated, which represents a large potential cost savings. Much of the SIB functionality may not be required to support payload training. The required SIB functionality for payload training could potentially be implemented in software for less cost. The use of the SDP for the local host and the use of DMS software would help assure that payload simulation control software and payload models executing on the local host could be easily integrated into the DMS environment.

The disadvantages of eliminating the SIB can not be ignored. There may be difficulties in using software models developed using the SSE without the SIB. The insertion of faults and instructor control may generally be more difficult without the SIB.

IV. <u>SCS Integrated Conceptual Design 3-C/D</u>

Integrates the Distributed Network Local Host architecture with the synthesis of the PCTC-based trainer and the Distributed Non-DMS trainer. This architecture does not have a DMS Kit or DMS components. Some trainer functions are implemented on the trainer host and some functions are implemented on dedicated processors.

This design also utilizes a distributed network. The trainer design, with no DMS hardware components, offers flexibility of hardware configuration, and reduces risk resulting from uncertainties in the DMS Kit development schedule. In addition, COTS non-DMS hardware can be readily purchased from a vendor, and is certain to be less expensive than DMS hardware. The use of non-DMS hardware does not necessarily preclude the use of DMS software. It is likely, however, that DMS software would require some degree of modification to run in a non-DMS hardware environment.

The disadvantages of a non-DMS trainer are significant. A PTC developed version of DMS software would be expensive and entails risk, whether or not DMS software modules are incorporated. Also, as changes are made to DMS software, the PTC DMS software would also have to be updated. Another important factor is that payload models must be transportable to the SSTF. This would be difficult to achieve with a non-DMS design, but not impossible.

V. <u>SCS Integrated Conceptual Design 2-A</u>

Integrates the Programmable Switch with multiple host architecture with the DMS Kit trainer design. In this design, multiple trainers may be interfaced to the same host. The trainers may be switched and reconfigured quickly in the event of a host failure.

The use of shared hosts makes maximum use of system resources. Any trainer can be quickly configured with any host, providing increased flexibility and fault tolerance. The use of dedicated point to point interfaces between the trainers and the hosts ensures that communication bandwidth problems are minimized.

There are disadvantages to using switches to connect trainers to shared hosts. A complex programmable switch is needed to connect any trainer to any host. The complexity is increased since different SCS facilities will likely have different host interfaces. For example, DMS-based trainers have a different host interface than non-DMS trainers or POIC trainers. Communications between trainers is awkward, since communications must pass through an intermediate host. Networks are less complex and more flexible than switched point to point connections.

VI. SCS Integrated Conceptual Design 3-A/D

Integrates the Distributed Network Local Host architecture with a combination of the DMS Kit trainer and the Distributed Non-DMS trainer. In this design, Non-DMS trainer elements are integrated with DMS trainer elements. Non-DMS trainer elements such as generic processors and peripheral devices are directly connected to the DMS LAN, instead of being directly connected to the SIB. In addition, elements of the Combined system approach are implemented in that the trainer host and SIB are shared across multiple trainers.

This design is similar to 3-A (# I) above. The use of some non-DMS components in the trainer provides additional flexibility, and allows increased trainer functionality. Functional areas where non-DMS components could be desirable are instructor control and monitoring audio/video systems, Core systems interface, and payload simulation control. These areas are envisioned to be implemented on the trainer host in other designs, but there could be advantages to implementing these functions in a processor directly attached to the payload LAN.

The SCS team recommends the six designs discussed above for entry into Task 5 - Refine SCS Conceptual Designs. The first step in the Task 5 evaluation process is the relative ranking of the candidate SCS conceptual designs. The six designs will be evaluated, and MSFC will identify the most compelling candidate designs which will subsequently be developed into detailed SCS designs.

APPENDIX A

SCS INTEGRATED CONCEPTUAL DESIGNS

I. SCS Design 3-A
(Network Local Host - DMS Kits)

Key:
- ● Totally Meets Requirement
- ◐ Partially Meets Requirement
- ○ Requirement Not Met

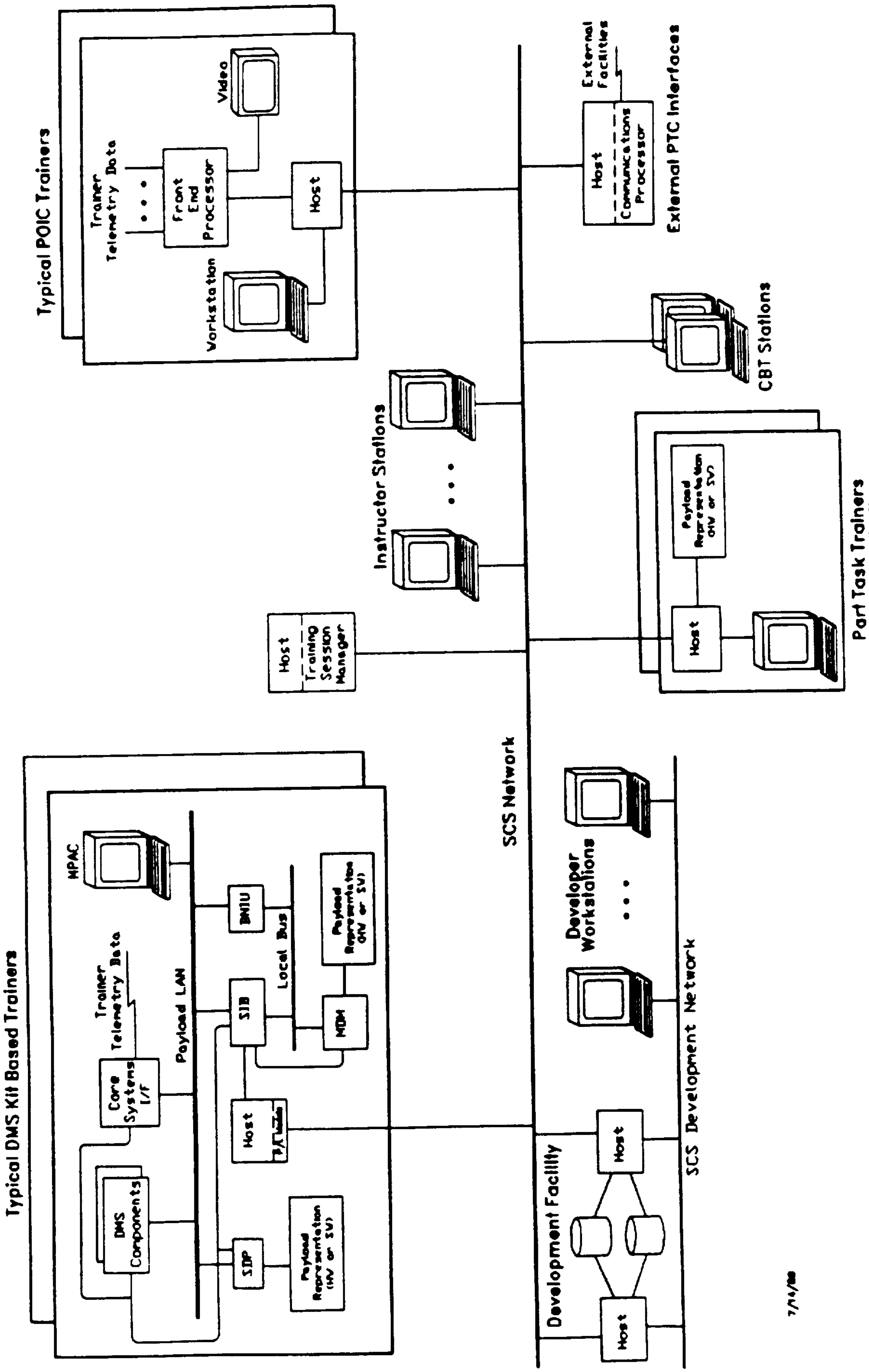
SYSTEM DESIGN COMPONENTS

SCS FUNCTION	GP Host - Central	GP Host - Simulation	GP Host - Trainer	GP Host - Payload	Payload Instrument	C&D Emulator	DMS MDM w/EDP	DMS SDP	DMS MPAC	DMS P/L Network	Time Gen Subsys	SIB	Audio/Video System	P/L Stimulation H/W	GP Workstation	GP Terminal	Data Switch	SCS Network	Network Bridge/Gatewy
DMS Representation							◐	◐	◐	◐	◐	◐							◐
Core Systems Representation								●											
C&T System Representation								●											
Payload Representation			◐		◐		◐	◐											
Crew Interface Representation					◐	◐			◐										
Simulation Executives			●																
POIC-DMS Interface								◐									◐		
PTC-POIC Link	◐																◐		◐
Payload Stimulator			◐				◐					◐		◐					
GSE Control			◐									◐							
Instructor Control and Monitoring			◐												◐			◐	
Training Session Management	◐		◐															◐	
Operator Control & Monitoring	◐		◐													◐		◐	
Configuration and Setup	◐		◐									◐						◐	
Training Analysis	◐		◐															◐	
Training Information Management	◐		◐															◐	
POIC Personnel I/F Representation			◐												◐				
PTC External Interfaces	◐																	◐	◐
Audio/Video System Representation			◐										◐						
Primary Instructional Delivery	◐														◐			◐	
Simulator, Scenario, & DB Dev.	◐														◐			◐	
Developer Interface	◐														◐	◐		◐	
Crew Interface Prototyping	◐														◐				
Integrate & Test Simulators			◐			◐	◐	◐	◐	◐		◐		◐				◐	

Allocation of SCS Functions to Design

I. SCS Integrated Conceptual Design 3-A

(Network Local Host - DMS Kits)



II. SCS Design 3/5-A
(Network Local Host/Shared Host - DMS Kits)

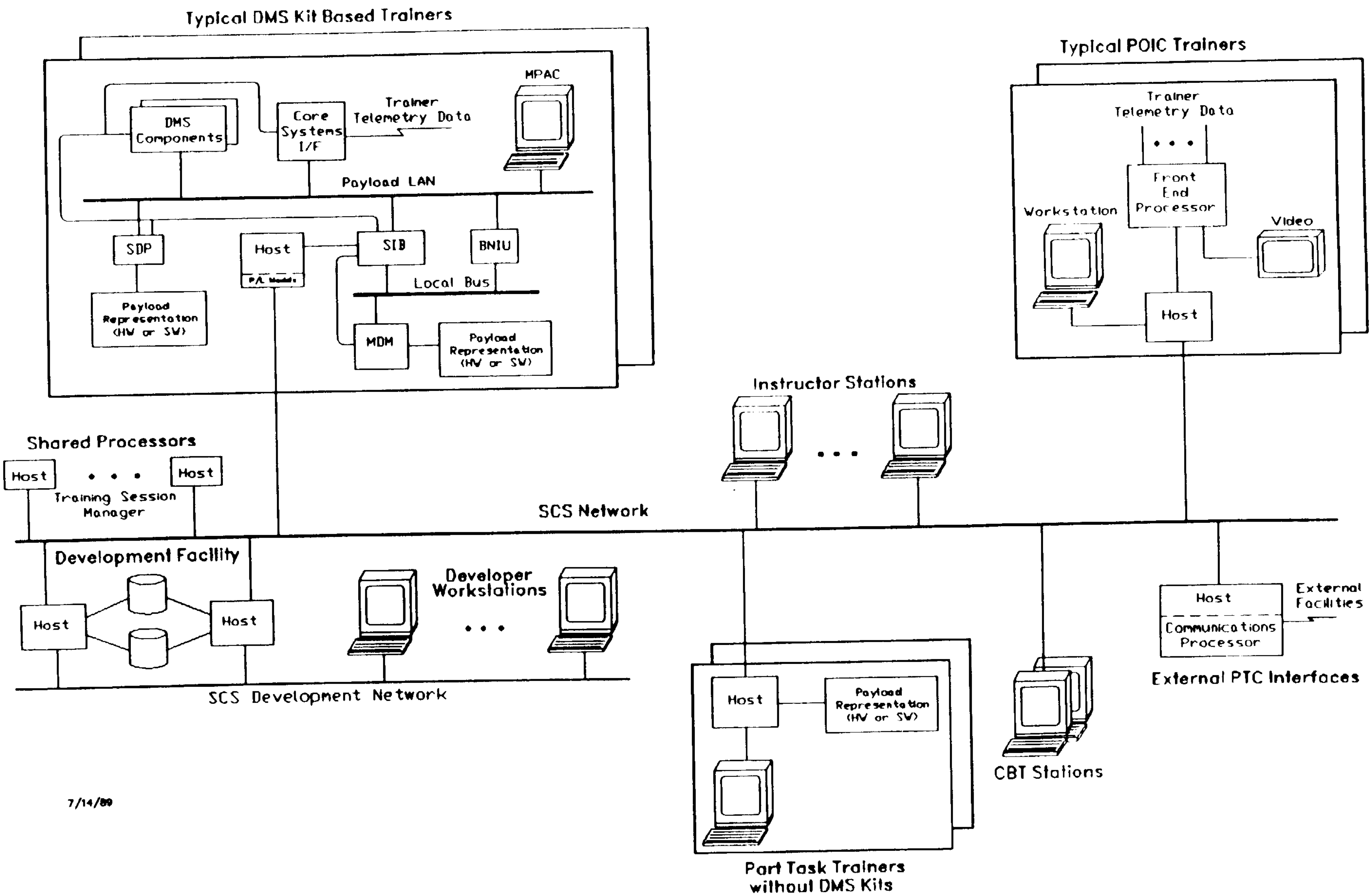
Key:
- ● Totally Meets Requirement
- ◐ Partially Meets Requirement
- ○ Requirement Not Met

SCS FUNCTION	GP Host - Central	GP Host - Simulation	GP Host - Trainer	GP Host - Payload	Payload Instrument	C&D Emulator	DMS MDM w/EDP	DMS SDP	DMS MPAC	DMS P/L Network	Time Gen Subsys	SIB	Audio/Video System	P/L Stimulation H/W	GP Workstation	GP Terminal	Data Switch	SCS Network	Network Bridge/Gatewy
DMS Representation							◐	◐	◐	◐	◐	◐							◐
Core Systems Representation								●											
C&T System Representation								●											
Payload Representation			◐		◐		◐	◐											
Crew Interface Representation					◐	◐			◐										
Simulation Executives			●																
POIC-DMS Interface								◐									◐		
PTC-POIC Link	◐							●									◐		◐
Payload Stimulator			◐				◐					◐		◐					
GSE Control	◐		◐									◐							
Instructor Control and Monitoring	◐		◐												◐			◐	
Training Session Management	◐		◐															◐	
Operator Control & Monitoring	◐		◐													◐		◐	
Configuration and Setup	◐		◐									◐						◐	
Training Analysis	◐		◐															◐	
Training Information Management																			
POIC Personnel I/F Representation			◐												◐				
PTC External Interfaces	◐																	◐	◐
Audio/Video System Representation			◐										◐						
Primary Instructional Delivery	◐														◐			◐	
Simulator, Scenario, & DB Dev.	◐														◐			◐	
Developer Interface	◐														◐	◐		◐	
Crew Interface Prototyping	◐														◐				
Integrate & Test Simulators			◐			◐	◐	◐	◐	◐		◐		◐				◐	

Allocation of SCS Functions to Design

II. SCS Integrated Conceptual Design 3/5–A

(Network Local Host/Shared Host – DMS Kits)



III. SCS Design 4-B
(Network Local Host with Combined Components - DMS Compatible)

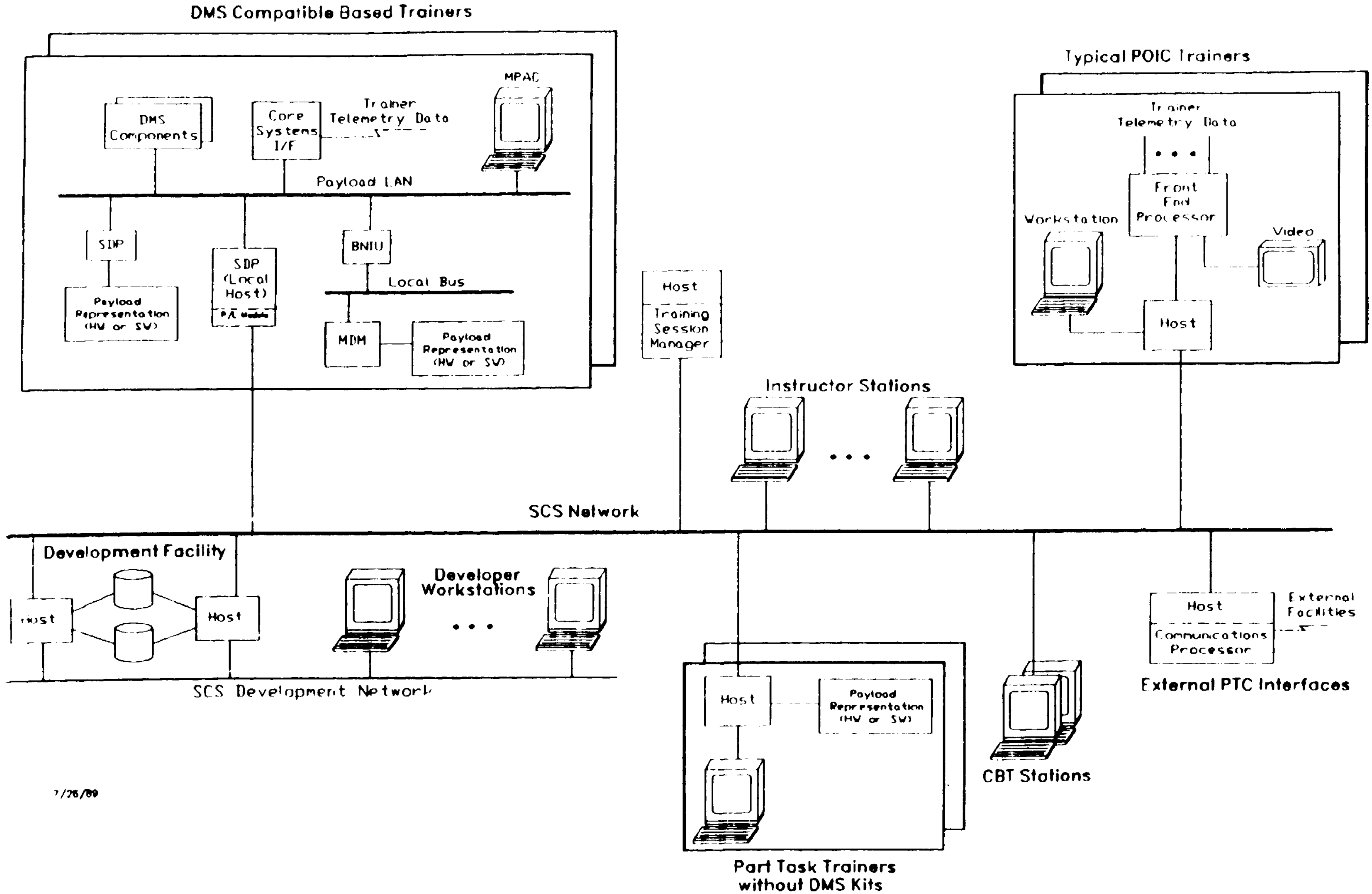
Key:
- ● Totally Meets Requirement
- ◐ Partially Meets Requirement
- ○ Requirement Not Met

SCS FUNCTION	GP Host - Central	GP Host - Simulation	GP Host - Trainer	GP Host - Payload	Payload Instrument	C&D Emulator	DMS MDM w/EDP	DMS SDP	DMS MPAC	DMS P/L Network	Time Gen Subsys	SIB	Audio/Video System	P/L Stimulation H/W	GP Workstation	GP Terminal	Data Switch	SCS Network	Network Bridge/Gatewy
DMS Representation							◐	◐	◐	◐	◐								◐
Core Systems Representation								●											
C&T System Representation								●											
Payload Representation					◐		◐	◐											
Crew Interface Representation					◐	◐			◐										
Simulation Executives								●											
POIC-DMS Interface								◐									◐		
PTC-POIC Link	◐							●									◐		◐
Payload Stimulator							◐	◐						◐					
GSE Control								◐											
Instructor Control and Monitoring								◐							◐			◐	
Training Session Management	◐							◐										◐	
Operator Control & Monitoring	◐							◐								◐		◐	
Configuration and Setup	◐							◐										◐	
Training Analysis	◐							◐										◐	
Training Information Management	◐							◐										◐	
POIC Personnel I/F Representation			◐												◐				
PTC External Interfaces	◐																	◐	◐
Audio/Video System Representation								◐					◐						
Primary Instructional Delivery	◐														◐			◐	
Simulator, Scenario, & DB Dev.	◐														◐			◐	
Developer Interface	◐														◐	◐		◐	
Crew Interface Prototyping	◐														◐				
Integrate & Test Simulators							◐	◐	◐	◐				◐				◐	

Allocation of SCS Functions to Design

III. SCS Integrated Conceptual Design 4 B

(Network Local Host with Combined Components - DMS Compatible)



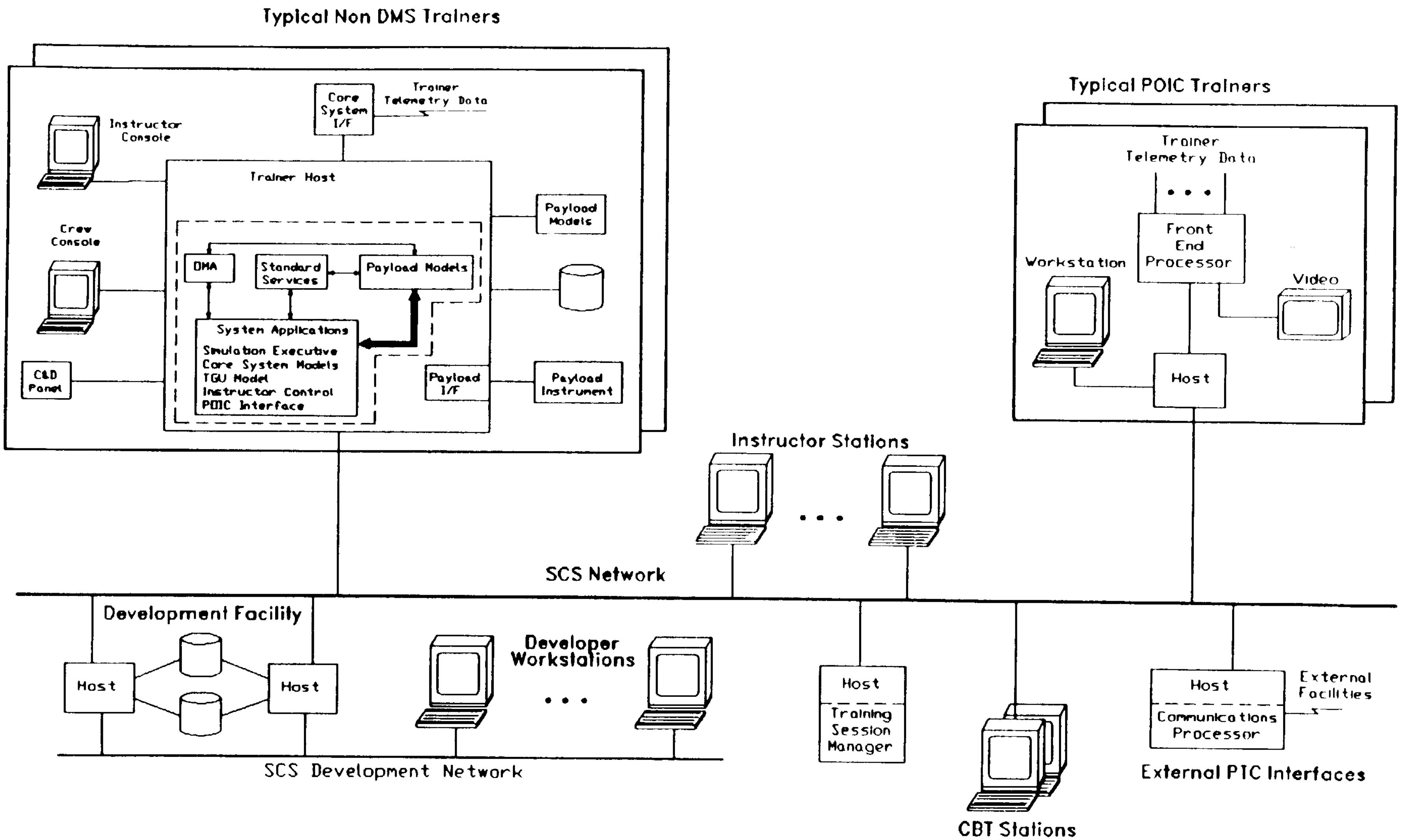
IV. SCS Design 3-C/D
(Network Local Host - PCTC Based/Non-DMS)

Key:
- ● Totally Meets Requirement
- ◐ Partially Meets Requirement
- ○ Requirement Not Met

SCS FUNCTION	GP Host - Central	GP Host - Simulation	GP Host - Trainer	GP Host - Payload	Payload Instrument	C&D Emulator	DMS MDM w/EDP	DMS SDP	DMS MPAC	DMS P/L Network	Time Gen Subsys	SIB	Audio/Video System	P/L Stimulation H/W	GP Workstation	GP Terminal	Data Switch	SCS Network	Network Bridge/Gatewy
DMS Representation			◐																◐
Core Systems Representation			◐	◐															
C&T System Representation			◐	◐															
Payload Representation			◐	◐	◐														
Crew Interface Representation			◐		◐	◐													
Simulation Executives			●																
POIC-DMS Interface			◐	◐													◐		
PTC-POIC Link	◐			◐													◐		◐
Payload Stimulator			◐											◐					
GSE Control			◐																
Instructor Control and Monitoring			◐												◐			◐	
Training Session Management	◐		◐															◐	
Operator Control & Monitoring	◐		◐													◐		◐	
Configuration and Setup	◐		◐															◐	
Training Analysis	◐		◐															◐	
Training Information Management	◐		◐															◐	
POIC Personnel I/F Representation			◐												◐				
PTC External Interfaces	◐																	◐	◐
Audio/Video System Representation			◐										◐						
Primary Instructional Delivery	◐														◐			◐	
Simulator, Scenario, & DB Dev.	◐														◐			◐	
Developer Interface	◐														◐	◐		◐	
Crew Interface Prototyping	◐														◐				
Integrate & Test Simulators			◐			◐								◐				◐	

Allocation of SCS Functions to Design

IV. SCS Integrated Conceptual Design 3-C/D
(Network Local Host - PCTC Based/Non-DMS)



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V. SCS Design 2-A
(Programmable Switch - DMS Kits)

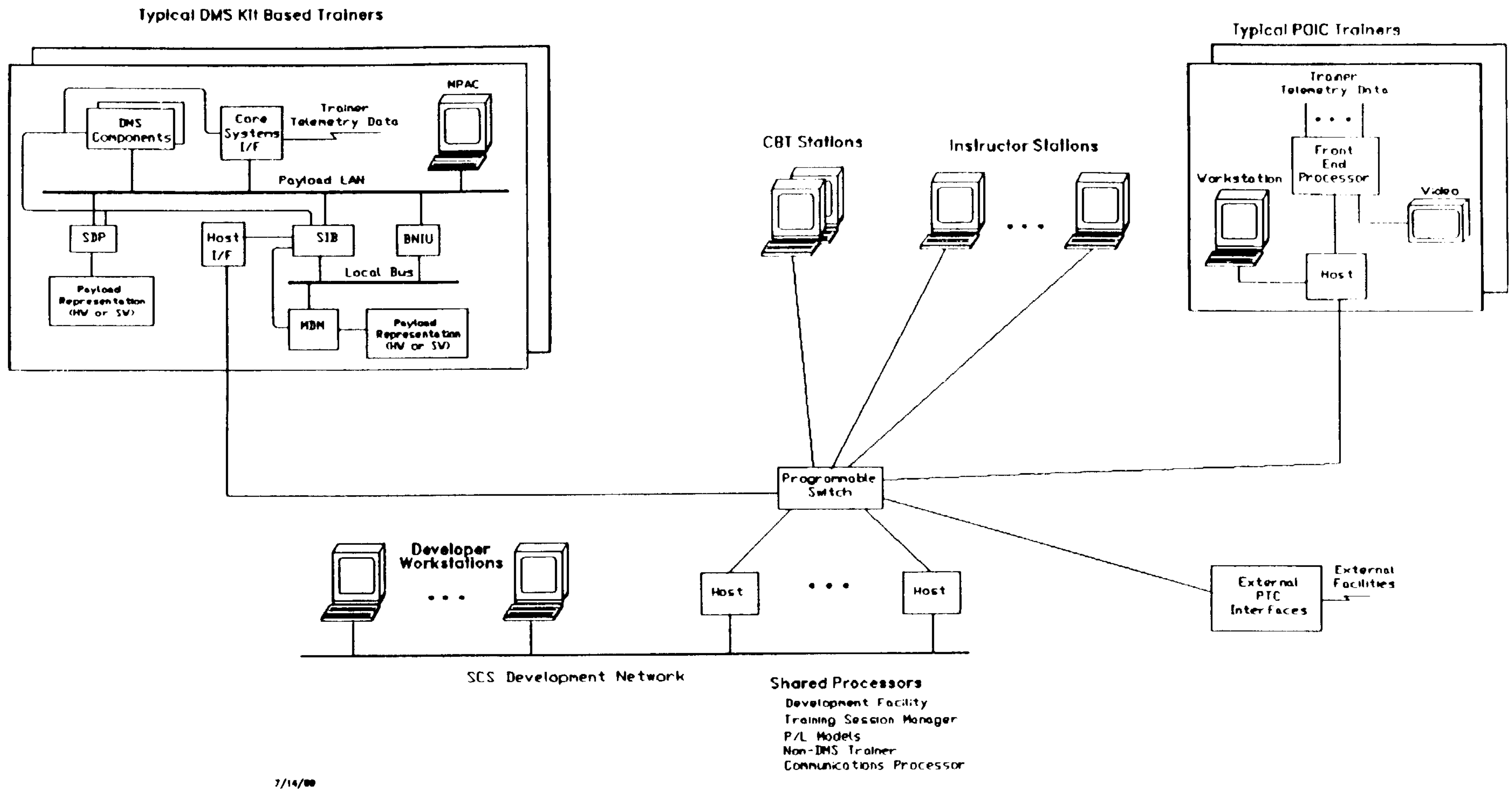
Key:
- ● Totally Meets Requirement
- ◐ Partially Meets Requirement
- ○ Requirement Not Met

SCS FUNCTION	GP Host - Central	GP Host - Simulation	GP Host - Trainer	GP Host - Payload	Payload Instrument	C&D Emulator	DMS MDM w/EDP	DMS SDP	DMS MPAC	DMS P/L Network	Time Gen Subsys	SIB	Audio/Video System	P/L Stimulation H/W	GP Workstation	GP Terminal	Data Switch	SCS Network	Network Bridge/Gatewy
DMS Representation							◐	◐	◐	◐	◐	◐							◐
Core Systems Representation								●											
C&T System Representation								●											
Payload Representation		◐			◐		◐	◐											
Crew Interface Representation					◐	◐			◐										
Simulation Executives		◐																	
POIC-DMS Interface								◐									◐		
PTC-POIC Link	◐																◐		◐
Payload Stimulator		◐					◐					◐		◐					
GSE Control	◐	◐										◐							
Instructor Control and Monitoring		◐													◐		◐		
Training Session Management	◐	◐															◐		
Operator Control & Monitoring	◐	◐														◐	◐		
Configuration and Setup	◐	◐										◐					◐		
Training Analysis	◐	◐															◐		
Training Information Management	◐	◐															◐		
POIC Personnel I/F Representation		◐													◐				
PTC External Interfaces	◐																◐		◐
Audio/Video System Representation	◐	◐											◐						
Primary Instructional Delivery	◐														◐		◐		
Simulator, Scenario, & DB Dev.	◐														◐		◐		
Developer Interface	◐														◐	◐	◐		
Crew Interface Prototyping	◐														◐				
Integrate & Test Simulators		◐				◐	◐	◐	◐	◐		◐		◐			◐		

Allocation of SCS Functions to Design

V. SCS Integrated Conceptual Design 2-A

(Programmable Switch - DMS Kits)



VI. SCS Design 3-A/D

(Network Local Host - DMS Kits/ Non-DMS)

Key:

- ● Totally Meets Requirement
- ◐ Partially Meets Requirement
- ○ Requirement Not Met

SCS FUNCTION	GP Host - Central	GP Host - Simulation	GP Host - Trainer	GP Host - Payload	Payload Instrument	C&D Emulator	DMS MDM w/EDP	DMS SDP	DMS MPAC	DMS P/L Network	Time Gen Subsys	SIB	Audio/Video System	P/L Stimulation H/W	GP Workstation	GP Terminal	Data Switch	SCS Network	Network Bridge/Gatewy
DMS Representation							◐	◐	◐	◐	◐	◐							◐
Core Systems Representation				◐				◐											
C&T System Representation				◐				◐											
Payload Representation			◐	◐	◐		◐	◐											
Crew Interface Representation					◐	◐			◐										
Simulation Executives			●														◐		
POIC-DMS Interface				◐				◐									◐		
PTC-POIC Link	◐																◐		◐
Payload Stimulator			◐	◐			◐					◐		◐					
GSE Control			◐	◐								◐							
Instructor Control and Monitoring			◐	◐											◐			◐	
Training Session Management	◐		◐															◐	
Operator Control & Monitoring	◐		◐													◐		◐	
Configuration and Setup	◐		◐									◐						◐	
Training Analysis	◐		◐															◐	
Training Information Management	◐		◐															◐	
POIC Personnel I/F Representation			◐												◐				
PTC External Interfaces	◐																	◐	◐
Audio/Video System Representation			◐	◐									◐						
Primary Instructional Delivery	◐														◐			◐	
Simulator, Scenario, & DB Dev.	◐														◐			◐	
Developer Interface	◐														◐	◐		◐	
Crew Interface Prototyping	◐														◐				
Integrate & Test Simulators			◐	◐		◐	◐	◐	◐	◐		◐		◐				◐	

Allocation of SCS Functions to Design

VI. SCS Integrated Conceptual Design 3-A/D
(Network Local Host - DMS Kits/Non-DMS)